3 UNDERGRADUATE EDUCATION

Summary of issues

The rise in the overall supply of science and engineering graduates in the UK in recent years masks reductions in the number of physical science and engineering graduates which are likely to have increasingly serious consequences for the UK.

The declining numbers of students taking relevant subjects at A-level are significant factors in these reductions. However, there are a number of issues relating to students' transition to higher education, and their experiences of higher education itself that also contribute to these trends. These include:

- mismatches between school-level physical sciences and mathematics courses and undergraduate courses in related subjects (which prevent some students making the transition to higher education smoothly);
- the length and perceived difficulty of science and engineering degrees – in particular, the extent to which four year degrees and more structured study in many science and engineering courses act as a disincentive to studying these courses;
- the legacy of under-investment in universities' teaching laboratories, which has resulted in around half the teaching facilities in universities being judged as unsatisfactory (this is particularly the case for science and engineering courses that require expensive and up-to-date laboratories and equipment, without which the degree is less attractive and relevant);
- the lack of adequate information for science and engineering students on employment opportunities and postgraduate study options; and
- the apparent mismatch between the mix of skills and aptitudes possessed by SET graduates and those needed by businesses.

The Review makes a number of recommendations aimed at:

- improving the links between schools and universities to ensure that students are better able to make the transition to undergraduate degrees in science, engineering and mathematics smoothly;
- addressing the perception among prospective students that degrees in these subjects are relatively hard to succeed in and require too much work;
- improving the laboratory teaching facilities in universities in science and engineering subjects; and
- ensuring that science degrees provide graduates with the skills that employers need and value, and that there are rewarding career paths into further study and academia.

Higher education in England[80]

3.1 Individuals' interest in higher education (HE) develops at different points in life. Although mature students account for a significant proportion (20-25 per cent)[81] of both full- and part-time students in higher education, the majority of the undergraduate student body is still comprised of 18-21 year olds who have entered higher education more or less directly from further education colleges or secondary schools. This chapter concentrates mainly on this latter group and the issues affecting them. It sets out some background information about higher education before exploring issues affecting the demand for science and engineering courses. It also considers factors affecting the quality of students studying these courses, both as they enter higher education and as they graduate.

Funding of higher education

The current higher education funding system for Higher Education Institutions (HEIs) in England allocates block grants on the basis of the number and type of students at the institution; and the volume, quality and subject of research undertaken by the institution. Individual HEIs then choose how to use that funding within guidelines set out by the Higher Education Funding Council for England (HEFCE). Similar systems operate in Scotland, Wales and Northern Ireland. Public funds for research are also available from the Office of Science and Technology (OST), via the Research Councils, to assist research projects and some postgraduate studentships. Funding is also available to encourage HEIs to work closely with employers and their local communities.

Not all subjects are equally expensive to teach. To reflect this, some subjects attract more support per student from HEFCE than others. This is done by setting 'subject premia' for different types of academic subject according to the cost involved in running the related courses. Similar subject premia are used in other parts of the UK.[82]

Since 1998/99 undergraduate students have also been required to pay their HEI a tuition fee (now around £1,100), which covers around one quarter of the average cost of their tuition. However, for many students, part or all of the fee is waived on the basis of means testing.[83] Undergraduates are also expected to pay for their living costs each year, and receive a student loan of £3,390-3,905 (£4,175-4,815 in London; £2,700-3,090 for those living at home).[84]

Postgraduates on taught courses such as the MSc[85] often pay fees to universities from their own funds. These can be raised through career development loans or company sponsorship. Fees for research postgraduates are often paid for by the Research Councils or other sponsors, or from university funds.

[80] The Review was commissioned by the UK Government, and this report therefore focuses on its areas of responsibilities. The higher education systems in Scotland, Wales and Northern Ireland have significant differences from higher education in England.

[81] *Supply and demand in higher education,* HEFCE 01/62, October 2001 and *UCAS 2001 entry statistics*, UCAS, Feburary 2002.

[82] In Scotland, the premia system has just been reviewed, resulting in a decrease in the number of categories covered, but there remains a much wider range of premia than in England.

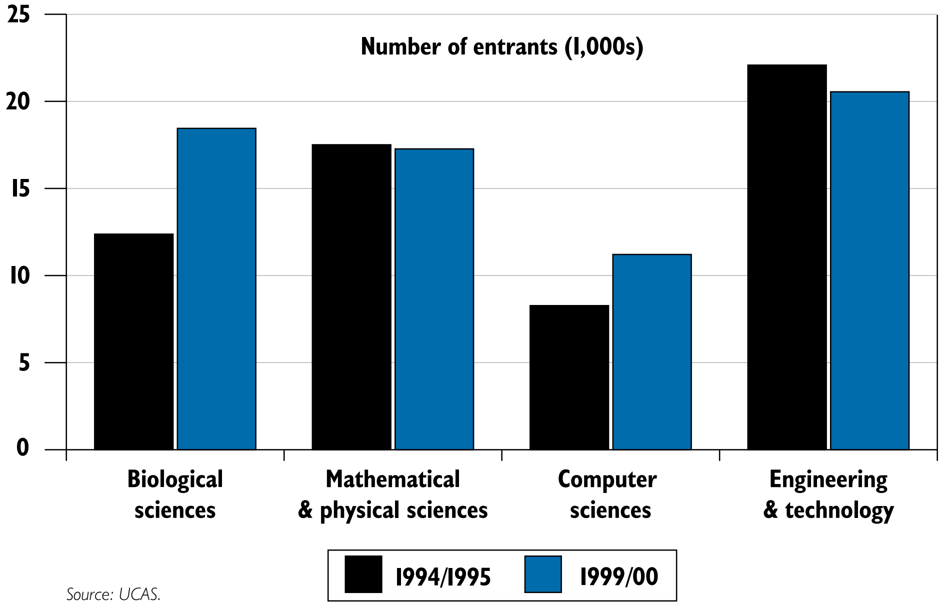
[83] Extra help is available for some students such as single parents, students with dependants and students with disabilities, and students in financial difficulty can also apply for assistance.

[84] Scottish students do not pay upfront tuition fees, following the 1999 Cubie report. The Welsh Assembly proposed in the 2001 Rees report that tuition fees for degree courses should be deferred until after students graduate.

[85] Master of Science (for further details see Chapter 5).

3.2 Just over 40 per cent of young people under the age of 30 enter higher education in the UK, of whom nearly a quarter (around 60,000) are accepted to study science and engineering subjects.[86] The numbers of science and engineering students are bolstered by sports science, computer science[87] and biology while the popularity of the physical sciences, mathematics and engineering has declined. This is illustrated in Figure 3.1 below. Subject areas in decline are discussed in more detail later in this chapter.

Figure 3.1: Changes in numbers of entrants onto SET courses, 1994/95 to 1999/00



Source: UCAS.

3.3 One third of all those accepted onto SET courses are women, although the proportions vary according to subject as shown in Figure 3.2. Men dominate the fields of computer science, engineering & technology, mathematics and physics,[88] whereas two thirds of biological science students are women. Biological sciences is the only SET subject area at undergraduate level where women account for more than 50 per cent of the total student population, and the proportion is increasing over time. This trend is attributed to various factors, including the ability of girls to relate to different areas of the science curricula and the high proportion of female science teachers who have a background in the biological sciences.

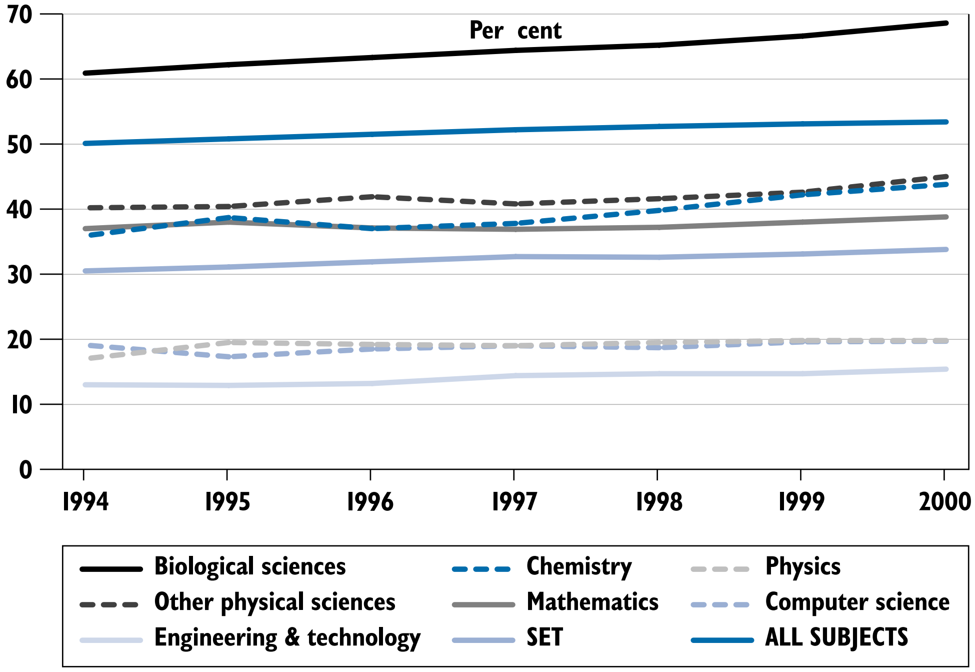
[86] *UCAS 2001 entry statistics*, UCAS, February 2002.

[87] *Scientists and Engineers: A study paper on the flow of students with A levels into full time undergraduate courses of study*, Council for Science and Technology, (to be published April 2002).

[88] *The UK Graduate Career Survey 2001*. The Times, 2001.

3.4 Within the other sciences and engineering, the proportion of women is around 30 per cent. The proportion of women has slightly increased between 1994 and 2000 in chemistry and other physical sciences, which includes earth, material and environmental sciences. Participation by women in undergraduate physics, mathematics and engineering & technology has remained low and static.

Figure 3.2: Proportion of female entrants to SET courses by subject, 1994 to 2000

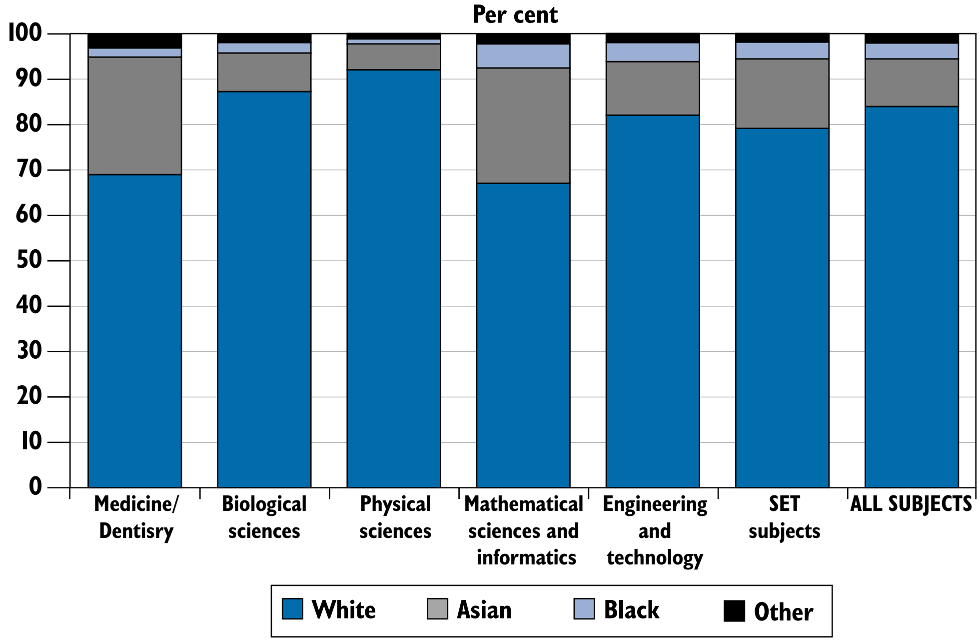


Source: UCAS.

3.5 Figure 3.3 below shows the ethnic balance of students in science and engineering compared to other subjects. The two most prominent points that emerge are the high proportion of Asian students studying medicine/dentistry and the high proportion of students studying the physical sciences who classify themselves as White. It is interesting to note that the gender balance within the group of African Caribbean students is reversed for science and engineering, compared to the white population, with women outnumbering men.[89]

[89] Note: for clarity a gender breakdown has not been included in Figure 3.3.

Figure 3.3: Ethnicity of SET course entrants in 2000



Source: UCAS.

Changes in demand for SET courses

3.6 The primary driver of change in HE course provision is student choice. Figure 1.4 in Chapter 1 illustrated that the number of undergraduates in SET was rising overall, driven by growth in biological science and computer science. However, fewer are studying for first degrees in the physical sciences (a fall of nearly 800 students between 1996 and 2000, or 8 per cent of the 1996 level[90]) and mathematics (172 fewer students, a 5 per cent fall). The proportion of all students studying engineering was down 0.8 per cent in the same period.

3.7 Furthermore, UCAS data[91] shows a decline between 2000 and 2001 in the number of students entering degree courses in chemistry (down 8 per cent), engineering (down 5 per cent), and mathematics (down 1 per cent, but predicted to fall by up to 12 per cent next year on the basis of applications currently received). The figures for physics entrants were about the same for the two years, although between 1996 and 2000 there was a 7 per cent decline in the number of entrants. Entries to first degree courses over a slightly longer period of time are presented in Table 2.2 in Chapter 2, which also demonstrates these declining trends.[92]

3.8 In contrast, the number of students studying other courses such as media studies and cinematics has grown significantly in recent years. Student numbers for these subjects were up by 22.1 per cent and 16.5 per cent respectively between 2000 and 2001 alone.

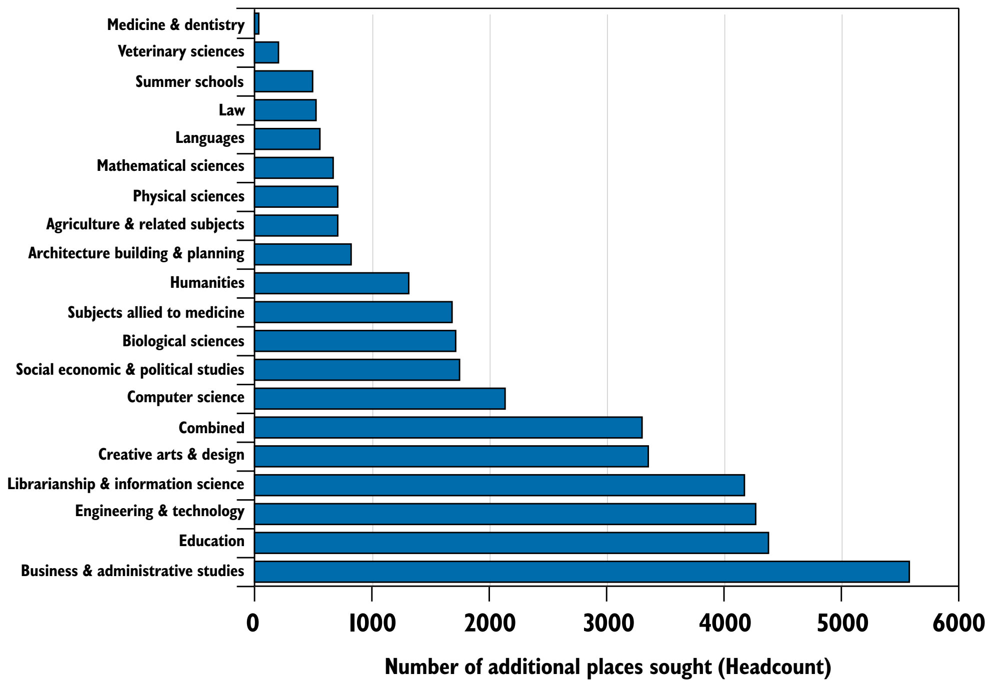
[90] *Scientists and Engineers: A study paper on the flow of students with A levels into full time undergraduate courses of study,* Council for Science and Technology, (to be published April 2002).

[91] *18,000 more students enter higher education in 2001,* UCAS press notice, January 2002.

[92] Note: in Table 2.2 the physical sciences are not separated.

3.9 A picture of how HEIs are responding to these changes can be drawn from bids for additional student numbers. Before January 2002, HEFCE used to set a Maximum Allowable Student Numbers (MASN) figure for each HEI in England as a means of controlling public expenditure on student support. Additional student places were awarded to institutions in response to competitive bids (based on predicted areas of growth in certain subjects). HEFCE's figures relating to these bids, presented below in Figure 3.4, are a good source of information about areas of growth or change in course provision in academic year 2001/02; figures for 1999/00 are similar.

Figure 3.4: Bids for additional student numbers in 2000/01 by subject



Source: HEFCE (The numbers given are expressed as headcounts incorporating both full-time and part-time students).

3.10 The subject areas showing most growth in student demand were outside SET. Within SET, there were high bids for additional engineering and technology places, and substantial demand for both biological sciences and computer science. The physical and mathematical sciences, however, had low bids for additional places.

3.11 These figures do not, however, show the number of student places lost through the closure of some courses, notably physics. Comparing the changing number of graduates in each SET subject, as shown in Figure 1.5 in Chapter 1, to the demand for additional places leads to the following conclusions:

Table 3.1: Changes in student numbers for SET subjects

Subject	Student demand	Demand for additional places	Possible conclusions
Biosciences	Increasing	Significant	HEIs are demanding and offering additional places and are therefore able to accomodate new demand
Computer science	Increasing[93]	Significant	HEIs are demanding and offering additional places and are therefore able to accomodate new demand
Engineering & technology	Fairly static/ falling slightly	High	Restructuring of engineering provision may be occuring, with some HEIs opening new courses, bidding for additional places and accomodating demand, while others are closing departments or dropping certain courses as a result of falling demand
Physical sciences and mathematics	Falling	Low	Limited restructuring is occurring in these subjects, mostly in terms of closing or downsizing departments

Source: Review.

The quality of science and engineering undergraduates

3.12 There are concerns that the decline in pupils taking science A-levels, other than biological sciences and computer studies, may be reducing the quality of the SET undergraduate intake, and hence the quality of SET graduates. This problem arises if students of lower ability are accepted onto science courses to make up numbers as there is less competition for places. However, UCAS data on the A-level points scores of science and mathematics entrants to HE[94] show an increase in the period 1996-2000, with the exception of some individual subjects (by far the worst of which was computer systems engineering, where average points scores fell 15 per cent). Although these increases in average points scores are not as large as the increase in the proportion of students achieving A-level grades A and B in the same period, the average quality of entrants to SET degrees as measured by A-level points seems to have risen rather than fallen. This suggests that the overall entry standard of science and engineering students may have risen, although the rise has not been as great as in other subjects.

3.13 Paradoxically, the high levels of attainment at A-level of scientists and mathematicians entering SET degrees may contribute to the impression that these qualifications are 'hard' in the sense of attracting a higher proportion of able students. The proportion of mathematics entrants with 30+ A-level points was 34 per cent in 2000, while 26 per cent of physicists and 16 per cent of chemists had similar scores. Under 10 per cent of biologists and only

[93] Intake was 75% higher in 2000 than in 1996 (9,204 students as opposed to 5,252); source: UCAS.

[94] *Scientists and Engineers: A study paper on the flow of students with A-levels into full time undergraduate courses of study*, Council for Science and Technology (to be published April 2002).

5 per cent of computer scientists achieved similar levels of attainment. The less ostentatiously difficult subjects are the ones in highest demand by students. By way of comparison, only 19 per cent of history entrants, 15 per cent of new economists and 1.8 per cent of sociology entrants had 30+ A-level points.

3.14 The output of higher education is of course not solely determined by its input quality, but also by the quality of teaching in HEIs and the motivation of individual students. Having said that, it is also vital to the success of degree level study for entrants to have at least minimum standards of skills and knowledge, as a basis to build upon. Deficiencies of A-level students (particularly in mathematics) which affect the output quality of SET higher education are discussed later in this chapter.

Factors affecting undergraduate education

3.15 There are a number of issues that influence both students' demand for SET degrees and the skills they develop during the degree. These include:

- students' ability to make a smooth transition from school or further education to higher education (including concerns about difficulty of the course);
- the appeal of the structure and content of the course;
- the teaching facilities for SET subjects;
- the length of the course and the impact of student debt; and
- the employment prospects resulting from the course.

3.16 Employment prospects are particularly important, as students increasingly want to be sure about the type of job they are likely to be able to get and what they are likely to earn as a result of their degree.[95]

The transition from school and further education to higher education

3.17 As noted in Chapter 2, science and mathematics appear to be 'hard' subjects at school, and this perception carries forward into higher education. Degree level study is (rightly) more demanding than A-level but it is important for this level of rigour to be appropriate both to the subject (bearing in mind the needs of potential employers) and to the abilities of the student intake. If SET subjects are perceived as 'hard' without being equally rewarding in terms of degree class or career potential, they will not be attractive to students.

3.18 The Review has noted an example of rigour within schools that, this year, has deterred students from degree-level study in mathematics. This is thought to be a result of the new AS-level mathematics, which was seen to be exceptionally 'hard' by pupils. As a result, pupils are not continuing to the full A-level, which in turn is leading to fewer applications to study mathematics at degree level. The difficulty of SET courses in HE seems to have a similar effect: why study theoretical physics when history is perceived as 'easier' and no less rewarding?

[95] *Grad facts 2000*, The Guardian, 2000.

Mismatches between A-level and undergraduate entry requirements

3.19 Much of the perception of increased difficulty of university over school SET education comes from the different levels of demand on SET students. This can be in practical work (a four-hour practical session at university is usually far more complex than a succession of one-hour classes in school) and in mathematical rigour. Improved conditions for practical work in schools, as proposed in Chapter 2, will help alleviate the first problem by improving pupils' experience of practical work. The problem of students' scientific and mathematical abilities requires further attention.

3.20 Many HE staff believe that current science and mathematics A-level syllabuses, while covering a wide variety of interesting areas, do not necessarily equip students with the intellectual and conceptual tools required at degree level. Reductions in the depth of knowledge required at A-level in favour of breadth and relevance of study, are seen by some to weaken the usefulness of the A-level as an indicator of a student's ability to tackle the more complex and in-depth work at degree level.

3.21 Schools are limited by the A-level syllabuses offered by examination boards but they do have an element of choice over the modules selected within these syllabuses. Curriculum choices are based upon the ability and knowledge of teachers, the need to offer a good education in the subject, and the desire to produce good results for the pupils and the school. In striving to achieve these aims it is possible that schools may sometimes lose sight of the requirements of university degree courses, and so fail to prepare pupils as well as they could.

Mathematical skills of university entrants

3.22 Mathematics A-level syllabuses were identified by the Review's consultation as not always providing a sufficient grounding for undergraduate study of mathematics or the physical sciences, both of which require a good grasp of algebra and calculus.[96] Good grades at A-level, even among bright students, do not necessarily reflect adequate knowledge of or ability to use core mathematical techniques. As a result, a number of universities run what they see as remedial courses in the first semester or first term of the degree course in order to bridge the gap.[97,98]

[96] A-level maths is also increasingly becoming an important grounding for the life sciences.

[97] Various research has been undertaken on mathematical skills of students, some of which suggest that students receive higher grades now than they would have in the past.

[98] *An Historical Study of the Correlation between GCE Advanced Level Grades and the subsequent academic performance of well-qualified students in a University Engineering Department,* K. Todd, *Mathematics Today*, Vol. 37 No. 5, IMA, 2001.

3.23 Mathematics A-levels contain a proportion of pure mathematics and at least one 'application' area – usually mechanics or statistics. The balance of subjects studied is generally chosen by schools. Until 2000 it was possible at A-level to cover a larger proportion of statistics than pure maths. The most recent QCA (Qualifications and Curriculum Authority) standards review report of mathematics at A-level[99] found a reduction in the level of pure mathematics ability demanded of students in the majority of the examining boards' A-level exams between 1995 and 1998. Pure mathematics content was judged to be less algebraic and more structured[100] or tested to a less demanding level.[101]

3.24 New course specifications to address this were introduced in September 2000. These new specifications gave effect to the changes proposed by the joint SCAA[102]/OFSTED report *Standards in Public Examinations, 1975-1995*, and reflected concerns raised by SCAA's Modular Question Paper review exercises and by Lord Dearing's *Review of Qualifications for 16-19 Year Olds*.

3.25 The current mathematics course specifications require 50 per cent or more pure mathematics and 25 per cent or more applications. However, they were found to be too challenging by teachers and students alike during 2000-2001, and produced a high failure rate in AS-mathematics in 2001. The QCA's report on phase two of Curriculum 2000 established that the changes from the 1995-2000 specifications had resulted in specifications that teachers could not readily deliver in the time available, and that students could not master in time for their AS examinations. The structure of these examinations is being reconsidered.

3.26 A-level mathematical specifications cannot easily return to the depth of, say, 15 years ago. However, it is important that in reviewing the A- and AS-level specifications, the QCA and awarding bodies consider the important role of A-level mathematics as a platform for degree level SET study. Nevertheless, HEIs must realise that the right balance is not one that overloads content and rigour into the A-level. A degree of flexibility in skills provision and knowledge at the school/HE interface is needed by HEIs.

[99] *Five year review of standards - A level mathematics,* QCA, 2001.

[100] This comment was made of the AQA/A board (Assessment and Qualifications Alliance (Associated Examining Board)) and of the CCEA (Northern Ireland Council for the Curriculum, Examinations and Assessment).

[101] This comment was made of the OCR (Oxford Cambridge and RSA Examinations) board.

[102] SCAA – the School Curriculum and Assessment Authority (the predecessor to the QCA).

A-level subject mix: breadth and depth

3.27 Another problem reported by some lecturers arises from the mix of A-level subjects taken by students. Those taking a mixture of scientific and non-scientific subjects can sometimes find their choices at degree level limited.[103] It is argued that this is one of the causes of the drop in students studying certain subjects, and the rise in students studying others. For example, physics A-level is a prerequisite (in some HEIs) for electronic engineering[104] but not for computer science. Some students apply to study computer science when they discover that they will not be accepted onto an electronic engineering course.

3.28 There is a wider debate on the need for 'broader' or 'deeper' education, as highlighted by the Council for Science and Technology's *Imagination and Understanding report*.[105,106] Both insufficiently broad education and insufficiently deep education create problems for potential employers and individuals. The Review is sympathetic to the benefits for many students of having a broader education than currently, although the issues discussed above must also be considered.

Addressing problems of A-level and degree standards mismatch

3.29 Schools, colleges and the curriculum and examination bodies need to strike the right balance between the relevance and attractiveness of the A-level to pupils and its content and rigour in terms of preparation for further study. HEIs also need to adapt their teaching and curricula to the needs of schools and students; this is discussed later in the context of undergraduate course content more generally.

3.30 One method used to smooth the transition between A-level and degree-level study is to give new students additional study courses at or before entry. This can be in person and/or through e-learning. The Review believes that these 'entry support courses' can be important in preparing students for degree-level work in the physical sciences and mathematics in particular. The Review would therefore like to encourage more of these entry support courses, which would ideally be residential and could run either before or alongside the start of the course, rather than extending the length of the course. The courses could be run in conjunction with local FE colleges and/or through the HEI's science and engineering departments. The aims of such courses would be:

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[103] The proportion of those students holding A-levels in three mixed science and non-science subject areas increased 15.6 per cent between 1996 and 2000. *Scientists and Engineers: A study paper on the flow of students with A levels into full time undergraduate courses of study*, Council for Science and Technology (to be published April 2002).

[104] *The labour market for engineering science and IT graduates: are there mismatches between supply and demand?* G Mason, National Institute of Economic and Social Research, March 1999.

[105] *Imagination and understanding: A report on the Arts and Humanities in relation to Science and Technology,* Council for Science and Technology, July 2001.

[106] One employer has said: "We want talented people who understand engineering not with a broad understanding of geography and whatever else you like to mention". Anonymous quote in *The Engineering Industry in the Next Two Decades: a Basis for Skills Outlook,* D Birchall, J-N Ezingeard and N Spinks, Engineering Employers' Federation, January 2002.

- to enable HEIs to provide new science and engineering undergraduates, particularly weaker students, with the opportunity to reduce knowledge gaps in maths and science and increase their confidence in these areas, in advance of starting undergraduate SET courses;
- to encourage students who had not previously considered science or engineering at university to apply or to remain on science and engineering courses instead of transferring or dropping out (as part of the widening participation in higher education agenda);
- to allow students the opportunity to establish important relationships with members of staff prior to the academic year beginning; and
- to address in the short term the problems of the knowledge of science and engineering course entrants, without requiring HEIs to reduce the academic rigour of their degree courses.

3.31 The entry support course approach is likely to be most effective for weaker students. This is because it introduces students to the subject that they will be studying at a higher level and to the university teaching and study environment. It is also a directed approach to learning rather than one that requires independent study, providing a bridge between the school-level mode of study and the degree-level mode of study. This may not be a suitable model for all HEIs and some might find it more appropriate to develop distance-learning material for new students.[107]

3.32 Such entry support courses and/or distance-learning are likely to become increasingly important given the Government's commitment to widening participation, which will increasingly lead to students entering universities with varied educational qualifications and backgrounds.

[107] Experience with the DfES summer schools system established in 1999 may be relevant to entry support courses, although the DfES summer schools have different aims – they are intended to give year 11 students (those who have just completed GCSEs) a taster of university or college life for a week.

Recommendation 3.1: Quality of SET A-level students as degree-level entrants

Students sometimes struggle to make the transition from A-level study to degree level study in science, engineering and mathematics, since undergraduate courses often do not pick up where the students' A-level courses ended. Furthermore, the increasing modularisation of A-level courses has led to students entering higher education with wider variation in subject knowledge (differences in the mathematical knowledge of students are seen to cause particular problems in mathematics, physical science and engineering degrees). The Review recommends that to help students – particularly those in the past least likely to participate in higher education – make the transition from A-level study to degree level study in science, engineering and mathematics:

- A-level awarding bodies and the HE sector should, review science, engineering and (in particular) mathematics education at the boundary between school/further education and higher education, and adjust their courses accordingly to ensure that this transition can be made smoothly; and
- the Government should fund HEIs to use new 'entry support courses' and e-learning programmes to 'bridge' any gaps between students' A-level courses and their degree courses.

Furthermore, the Government should in three years' time review progress in reducing the gaps between A-level and degree-level courses – to ensure that students are not discouraged from studying these subjects, and retain interest in them – and take further action as necessary.

Undergraduate course content and structure

3.33 Many students who take science and/or mathematics at A-level choose not to study science and engineering at degree level. Particular issues are that science and engineering courses are perceived by some potential students as:

- 'hard' in the sense of being conceptually difficult;
- 'hard' in the sense of taking considerable time and effort to study[108] (contact hours for SET typically exceed those for arts and humanities courses; more than 25 contact hours per week for scientists is not unheard of, whereas 10 or fewer contact hours is not uncommon for some arts and humanities courses); and
- unrewarding (both in the sense of personal satisfaction, where some argue that the heavily factual nature of SET courses is restrictive and unappealing, and in respect of the career opportunities which they open up).

[108] The distinction here is that while it takes a lot of effort to do well at any subject, the necessary minimum level of effort (and the average level of time spent) to study SET subjects or medicine is perceived to be much higher than that for many other disciplines. The fact that SET study involves 'visible' and timetabled contact hours, rather than unseen, flexible study at home or in libraries, may underlie this perception.

3.34 Schools face a difficult task in making science and mathematics both attractive to students and a sufficient preparation for further and higher education. Should universities and colleges take more account of the abilities and levels of knowledge that the students have on entry, and alter their courses accordingly? The difficulty HEIs face in undergraduate education is in taking account of the competing needs of a number of stakeholders:

- schools, who seek good A-level results and broad educations for their students, and face the temptation to choose easier course options in pursuit of the former goal;
- employers, who want both breadth and depth of skills from graduates, and the ability to apply them to commercial problems;
- universities, who as postgraduate educators and future employers of postgraduates, have a particular need for depth of skills and knowledge; and
- students themselves, with a need for HE courses in SET to be attractive to students (on whom a large part of an HEI's income depends).

3.35 Insufficiently challenging undergraduate courses might meet the needs of schools but fail to satisfy employers. Equally, overly challenging courses could produce a few extremely able students, but fail to attract enough other students to justify the continued running of the course. In recent years, universities have tended to err on the side of maintaining historical standards at the risk of alienating students. For example, the Quality Assurance Agency's (QAA) quality assessment of chemistry teaching in 1993/94 found that:

> *"The perception that there have been changes in science education in schools involving reductions in the factual content has, however, increased the temptation to overwhelm students with too much curricular material and too many class contact hours in undergraduate chemistry courses. As in any practically based subject, it is misleading to compare time spent in the laboratory with that spent in the classroom, but there has been general agreement that class contact hours need to be reduced to a level which provides the necessary theoretical and practical tuition, whilst allowing sufficient time for independent learning by students."*[109]

3.36 Similarly, in 1990, undergraduate physics and chemistry degrees were considered to be 'cramped' following enormous developments in science over the previous fifty years. The Institute of Physics-led 'Higher Education Working Party' concluded at that time that the content of degrees should be cut by a third, and that the MPhys 'fourth year' should be created to build on a more realistic three-year programme as a basis for advanced professional work in physics.[110] This effectively redistributed the content of a 'cramped' three-

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[109] QO 2/95 Subject Overview Report - Chemistry, QAA (1995), http://www.qaa.ac.uk/revreps/subjrev/All/qo_2_95.htm.

[110] *The Future Pattern of Higher Education in Physics - The Final Report of a Higher Education Working Party,* The Institute of Physics, The Standing Conference of Physics Professors & The Committee of Heads of Physics in Polytechnics, August 1990.

year programme over four years, and also served to maintain student numbers. It did this both by reducing the intensity of the course, thus making it less 'hard' and more attractive to students, and by keeping students for four years rather than three.

3.37 The recent Institute of Physics' inquiry into undergraduate physics[111] moved on from this argument to recommend that university physics departments should consider re-balancing the content of undergraduate degree courses, in order to strengthen mathematical skills, transferable skills, and adapt to "the changing knowledge base of new undergraduates without losing the excitement of physics".

How should HEIs respond in the long term to changes in school curricula?

3.38 This Review has already explored a short-term solution to dealing with the mismatches between A-level and degree level SET subjects, in the form of entry support courses. In the medium term HEIs need to adapt their courses to reflect changes in school curricula, as well as increasing the attractiveness of the subjects, and teaching skills and knowledge valued by employers.

3.39 Moves towards 'action learning' and 'contextual learning' are particularly welcome in this respect. These involve group-based learning as well as individual skills development (for example, discussing how best to conduct an experiment in a group before carrying it out individually). In general, approaches to learning which are familiar to students will tend to obtain better results, and will help enable HEIs to retain high levels of intellectual content and technical challenge.

3.40 The exact solution to the problem will be for individual HEIs to determine. The Government, as the major funder of education, should however ensure that the needs of schools, employers and students are taken into account, as recommended above.

SET degree course structure

3.41 Most science and engineering subjects tend to require, in the first instance at least, the study of considerable amounts of core knowledge.[112] Professional standards in SET (for example the SARTOR standards for MEng courses) further define the material which must be included in the course. Science and engineering degree courses therefore involve a high number of teaching hours to cover this core material, backed up by tutorial work and self-study. Students also have to develop practical skills in laboratory work, which increasingly involves the use of specialist equipment not found in schools.

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111 *Physics – building a flourishing future, Report of the Inquiry into Undergraduate Physics*, Institute of Physics, October 2001.

112 This is in contrast to some arts and humanities courses which allow students considerable flexibility in their study.

3.42 All of this requires a high number of contact hours for science and engineering students throughout their first degree courses. As core knowledge and skills have been acquired, students are in more of a position to explore the use of both of these elements on work placements, and more specialised areas of study. It is at this point that businesses can meet their own needs by influencing course design. They can also offer suitable placements for academic staff to bring them up to date with the industrial environment that they are preparing their students for and the R&D work that they are involved in on the behalf of businesses.

3.43 Lord Dearing in his report in July 1997 from the National Committee of Enquiry into Higher Education suggested that more undergraduate courses should offer industrial placements as part of the course. The report acknowledged that employers placed importance on the level of work experience that new recruits had attained, and that both staff and students at the universities that had taken part in work experience schemes benefited from the experience, particularly when it was a structured part of the course.

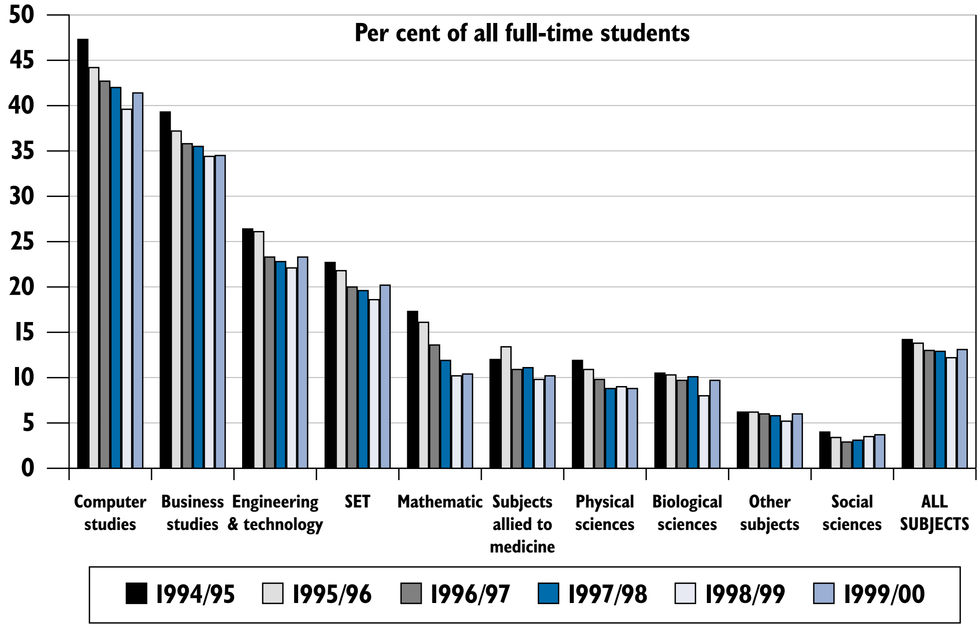
3.44 Figure 3.5 below shows that, in fact, fewer[113] undergraduates may be graduating in courses that offer industrial placements as part of the course,[114] although the proportion began to increase slightly in many cases in the academic year 1999/00. It is difficult to judge the reasons for this decline. It may be due to businesses and HEIs not collaborating effectively over these types of courses. Alternatively, students may simply be choosing to steer away from sandwich courses because they usually involve an extra year added to their course or, as commented on later in this chapter, they wish to avoid having to pay tuition fees for the sandwich year.

3.45 In the case of science and engineering, the Review believes that additional provision of structured work experience would help more students develop the skills that they need to work in SET businesses. It would also improve students' awareness of the job opportunities that exist in the sector. Student input into the choice of industrial placements, and businesses acting in collaboration with universities, could enhance the relevance of such placements to course options. HEIs should also strive to better market courses offering industrial experience, so as to encourage a wider take up of these opportunities.

[113] This is based on the assumption that industrial placements take place in sandwich years - of course some universities might encourage placements within vacation time, especially given that vacation employment is an increasingly common trend among undergraduates.

[114] This is not necessarily a true indication of the number of courses of this type that are on offer.

Figure 3.5: Sandwich students as a percentage of full-time first degree students, 1994/95 to 1999/00



Source: HESA.

Involving businesses in the development of SET courses

3.46 The National Committee of Enquiry into Higher Education recommended in 1997 that HEIs produce skills specifications for the courses that they offer, and identify ways of communicating these to industry representatives. At the same time, companies were recommended to take a strategic view of their relationship with higher education and to plan accordingly. This Review is concerned that there is little evidence of the outcome of these recommendations and/or (where they have been applied) their usefulness. Much work remains to be done to improve communication of skills needs and provision between both higher education institutions and companies of all sizes.

3.47 Universities usually liaise formally with businesses through industrial advisory boards. These involve representatives from different companies to advise on the curriculum. In practice, these boards often do not discuss skills needs with any coherence. In too many HEIs there seems to be no mechanism for feeding back any changes made to courses as a result of boards' input, and therefore no assessment of the value of the activity. This is not an effective way for businesses to communicate their skills needs to universities.

3.48 One difficulty HEIs face in altering courses to meet identified business needs is the rigidities imposed by professional bodies. These can both constrain the scale of changes and render the exercise more time-consuming if the course must be re-accredited after any appreciable change.

3.49 Occasionally companies seek to develop specific courses designed for their own needs, with a view to employing the graduates or influencing the R&D activity of the university.[115] The more usual relationship is not as direct, but skills communication appears to work best when universities are involved in regional and local partnerships based on particular business clusters or in the context of collaborative research. Chapter 6 describes a number of government-funded initiatives intended to encourage better collaboration between industry and the HE sector.

3.50 The Government announced in November 2001 that it would be providing £1 million over 2002-04 to improve the embedding of work-related skills more widely in HE provision. This will involve building on initiatives like Graduate Apprenticeships and foundation degrees[116] and transferring the good practice developed by individual HEIs more widely in the HE sector.

3.51 However, the Review is concerned that a step change is needed in the skills communications between employers (particularly businesses) and HEIs. Greater business involvement in course development would give HEIs, businesses and students more confidence that students are acquiring the right skills, and would keep businesses in touch with the skills sets on offer from universities.

Recommendation 3.2: Undergraduate course structure

Updating the nature and content of undergraduate courses to reflect the latest developments in science and engineering (through having lecturers who can draw on recent experience of work environments other than HEIs, and through explicit changes in course content) has the benefit of improving the attractiveness and relevance of the course to both students and employers. Accordingly, the Review recommends that employers and HEIs work more closely together, for example through:

- increasing the number of industrial placements offered to academic staff;
- encouraging industrialists to spend time in universities;
- encouraging greater engagement between businesses and careers services and, in turn, between careers services and science and engineering departments; and
- encouraging universities to be more innovative in course design in science and engineering.

These actions by HEIs and employers must be supported by those bodies that accredit science and engineering courses – for example, the Engineering and Technology Board and professional bodies which are members of the Science Council – who must work with universities to drive forward innovation in course design, and not allow the accrediting processes inadvertently to inhibit it. The Government should facilitate these forms of HEI/employer interactions through ‘third stream’ funding such as the Higher Education Innovation Fund (HEIF). Furthermore, the Government should in three years’ time review progress in this area and take action as necessary to further improve HEI/employer interactions.

[115] An example of this is the Masters course run in collaboration between BAe Systems and Loughborough University.

[116] Foundation degrees are targeted at meeting skills needs for higher technician and associate professional jobs, and combine academic study with work-based learning. The courses are intended to attract many people who do not currently enter higher education, and employers and employer bodies are actively involved in their design.

Undergraduate skills development via the proposed teaching assistants scheme

3.52 Currently some undergraduates and doctoral students have the opportunity to help out in schools on a voluntary basis through taking part in schemes like the Researchers in Residence scheme,[117] in which doctoral students support the teaching of science in schools. Such work helps give students practice and confidence in communicating and dealing with other people and using their knowledge practically. SET students are felt to lag behind their peers in the development of interpersonal skills, particularly as they tend to have less time in the academic curriculum to devote to personal development. Working in schools would help them to develop these skills, which are valuable to them in their future careers. In Chapter 2 the Review recommends the introduction of a teaching assistants scheme, under which undergraduates and postgraduates would be paid to support teachers in schools in the teaching of science.

University science and engineering teaching facilities

3.53 Teaching of science and engineering requires suitable facilities. All academic courses, including SET, require lecture theatre space, seminar rooms, computer suites and libraries. Science and engineering subjects also require specialised laboratories and equipment that are often more expensive than other disciplines. For example, teaching bioinformatics, an area in high demand by employers, requires considerable computing power to match the available software, and hence considerable investment in IT hardware. Some science courses require clean rooms or fume cupboards; some engineering subjects need to accommodate heavy product engineering equipment. There is a need for some of this workspace to be developed into multi-use computer-simulation labs, involving a reduction in space required, but a need for new, very different and expensive resources.

3.54 If science and engineering students (including postgraduates) are to be able to develop their research, technical, teamwork and project management skills effectively, they need to be working in an up to date environment with high quality equipment.[118] However, many SET laboratories are far from this standard. HEIs approached by the Review commented on the improvements required in their SET departments, and in some cases on industry's expectations that students should be taught using the type of equipment they are likely to encounter in industry.

3.55 There is also concern that teaching laboratories are poorly staffed. Use of specialist equipment demands expert supervision and demonstration, as does the preparation of experiments and the use of consumables. Increases in student-to-staff ratios have decreased the tutor/student interaction, although academic staff are generally assisted by postgraduate students and research

[117] See footnote 66.

[118] The quality of undergraduate laboratories can also affect postgraduate facilities, which are often co-located.

staff. Provided that this does not decrease the level of senior staff participation too far, this is beneficial to the undergraduates and also to the postgraduates, who gain communication skills experience and financial benefit.

3.56 Businesses benefit from HEIs having up-to-date equipment in teaching labs because it ensures their future labour supply is trained to use such equipment. Although Government has a role in helping HEIs to provide appropriate equipment, businesses can assist themselves by donating suitable equipment to educational establishments such as universities. The Government encourages this through tax reliefs for businesses on equipment donations to charities and to educational establishments.[119] The Review believes that such reliefs are useful in improving collaboration and in providing good quality equipment, and would like to see more businesses making use of them.

Is the cost of scientific equipment increasing?

3.57 One reason for under-investment in teaching laboratories is that the cost of scientific equipment has increased relative to HEIs' income. Between the mid-1980s and the end of the 1990s, business expenditure on R&D per full-time equivalent (FTE) worker[120] rose by approximately 45 per cent. Although the Review did not have at its disposal data to compare HE R&D spending over the same period (OECD data for HE expenditure ends in 1993), between the mid 1980s and 1993 expenditure by the higher education sector per FTE R&D worker remained fairly constant.

3.58 It is possible that since 1987 HE funding has not adequately taken account of capital overheads.[121] Certainly universities have consistently under-invested in SET teaching facilities. While the Government has recently, with the Wellcome Trust, directed significant sums to research equipment and infrastructure, there remains a need to deal with a backlog in teaching investment.

Summary of teaching facility issues

3.59 To improve the quality of scientists and engineers coming through UK universities, substantial investment is urgently required in university teaching laboratories. HEFCE's Estate Department estimates that about half of all teaching labs in the UK are in urgent need of refurbishment, many of them not having been modernised since the 1960s. The lack of investment in laboratory facilities is in part a result of HEIs directing funds to other areas where they are judged to be needed more urgently (staff costs, for example) in preference to spending on teaching infrastructure.

[119] HEIs usually fall into both these categories.

[120] Part-time employees count as a fraction of a full-time equivalent (FTE) worker. For example, if a full-time employee works 40 hours per week, a part-time worker who does 20 hours a week counts as 0.5 FTE worker.

[121] Prior to 1987 universities received their capital funding separately.

3.60 The backlog in teaching laboratory refurbishment is too large to be addressed simply by an increase in recurrent funding. It would take too long to bring the majority of labs up to an acceptable standard, and universities might, as previously, redirect funding to other needs.

Recommendation 3.3: University teaching laboratories

The Review recommends that the Government should introduce a major new stream of additional capital expenditure to tackle the backlog in the equipping and refurbishment of university teaching laboratories. The priority should be to ensure the availability of up-to-date equipment and then that, by 2010, all science and engineering laboratories should be classed as at a good standard or better, as measured by HEFCE. In delivering this recommendation, the Review believes it is important that the teaching infrastructure capital stream complements research infrastructure funding to facilitate the building, refurbishment or equipping of joint research and teaching facilities, where appropriate.

Recurrent funding for SET teaching

3.61 Laboratory based courses are inherently expensive to run given the costs associated with laboratories (chemicals, extra staff such as technicians for experimental classes, etc.), and the upkeep of the laboratories themselves. The Review has also found that academic salaries vary between different fields within SET. The per capita salary bills of physics and biological sciences departments usually proves greater than those of other departments, particularly engineering subjects and computer sciences.

3.62 The Review asked a sample of HEIs in England for information on their actual staff costs for science and engineering subjects, using history (where applicable) as a comparison. Respondents tended to put the average cost of full-time experienced lecturers/professors in history at around £45,000 p.a. In comparison, biological sciences ranged from £47,400 to £58,000 p.a., chemistry from £47,500 to £56,000 p.a., and physics from £49,000 to £56,500 p.a. Costs for engineering came in lower, ranging from £44,000 to £54,000 p.a. One university (not in London or the South East) however put science and engineering up to an average of £60,000 p.a.

3.63 On this evidence, SET *per capita* staff costs appear to be around £2,500-£15,000 per annum (or roughly 6 per cent to 33 per cent) greater than those for historians. Furthermore, as is shown in Chapter 5, a higher (and growing) proportion of academics in SET subjects are at senior levels, relative to most other disciplines. These are also subjects facing market pressures, as discussed in Chapter 5. All this is likely to mean higher overall cost differentials than the raw figures indicated above.

3.64 Funding for English HEIs' teaching costs is assigned by HEFCE on the basis of 'subject premia', which provide additional funding for subjects which are more expensive to teach, including most SET courses. These premia are set out in Table 3.2 below. The current premia were calculated using actual 1994/95 expenditure by institutions, which included staff salaries, cost of equipment etc. Although these values increase (at an inflationary rate) when they are reviewed each year, the cost weights have not changed since the subject premia were introduced in 1996.

3.65 For laboratory-based subjects these premia appear to be insufficient to allow universities to maintain their laboratories properly and to meet their staff and running costs. Given the systematic under-investment in teaching infrastructure described above, it is very likely that this under-investment was 'frozen-in' and has resulted in a continued under-resourcing of science and engineering departments. Furthermore, all the laboratory subjects are placed within the same price group, and do not differentiate between the staff costs of different science and engineering departments.

Table 3.2: HEFCE subject premia price groups

Price group	Description	Cost Weight	Approximate value per student (£ p.a. in 1995)[122]
A	The clinical stages of medicine and dentistry courses and veterinary science	4.5	12,915
B	Laboratory-based subjects (science, pre-clinical stages of medicine and dentistry, engineering and technology)	2	5,740
C	Subjects with a studio laboratory or field work element (includes mathematics and IT)	1.5	4,305
D	All other subjects	1	2,870

Source: HEFCE.

3.66 The cost of equipment and SET teaching staff has increased (and is still growing) relative to other subjects, and indeed there are differences within the costs of different subject areas within the same laboratory-based price group. These costs are greater than allowed for in the current funding maintain the quality of their laboratories and retain good teaching staff.

Recommendation 3.4: Recurrent funding for teaching

In order to ensure that in future higher education institutions can and do invest properly in science and engineering teaching laboratories, the Review recommends that HEFCE should formally review, and revise appropriately, the subject teaching premia for science and engineering subjects. The revisions should ensure that the funding of undergraduate study accurately reflects the costs – including paying the market rate for staff, as well as the capital costs – involved in teaching science and engineering subjects.

Student funding and debt

3.67 Student debt has increased in recent years from an estimated average of just under £2,500 in 1995/96 to around £3,500 in 1998/99.[123] More recently, reports[124,125,126] have suggested average student debt has between £6,000 and £12,000. However, despite increasing levels of debt, student expenditure on items such as mobile phones and socialising is in line with lifestyle patterns

[122] The values per student for each price group are presented in Table 3.2 at the recently announced 2002-03 levels, with a basic rate of £2,870 (compared to a basic rate of £2,600 when the premia were established in 1995).

[123] *Changing student finances: income, expenditure and the take-up of student loans among full- and part-time higher education students in 1998/9*, C Callender and M Kemp, South Bank University, December 2000.

[124] *Student living report 2002*, commissioned by Unite and conducted by MORI, January 2002.

[125] *Students 'would be better off on benefit'*, W Woodward, *The Guardian*, 20 February 2002.

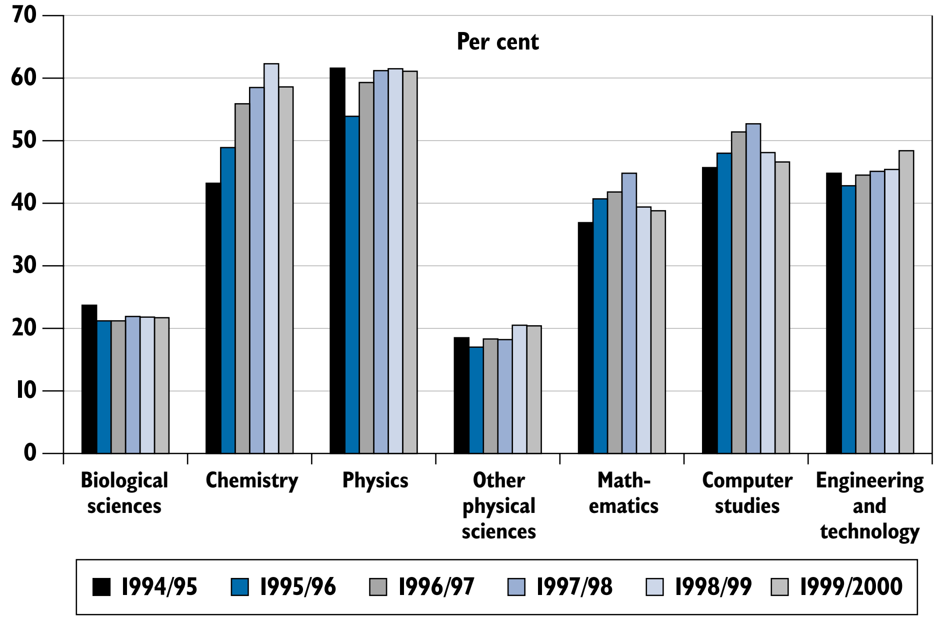
[126] *Barclays estimates total student debt at £4.85 billion, Barclays News Release*, 24 July 2001.

for 18-25 year olds in general. The Review did not find evidence that student debt is deterring students from undergraduate study in general. However, the Review gave further consideration to any effect of longer science and engineering courses on student choices.

Is the length of study deterring students from studying SET?

3.68 Until the 1990s, three-year undergraduate courses were normal for the majority of subject areas,[127] including science and engineering. During the mid 1990s, however, many universities began to offer four-year courses in some scientific subject areas, leading to an 'undergraduate' Masters qualification rather than a Bachelor's degree. The best established of these courses, the MEng (Master of Engineering), is the professional qualification for engineers.[128] For the most part, physical sciences and engineering courses, particularly within older HEIs, became four-year courses around this time. However, three-year courses continue to be offered, and in biology three-year courses are still relatively common (see Figure 3.6).

Figure 3.6: Proportion of SET first years expecting to study for over three years and less than four



Source: HESA.

[127] This model was specific to England, Wales and Northern Ireland, and differed in Scotland where four year honours courses have been the norm for some time.

[128] It is slightly different from other undergraduate Masters qualifications as it was devised in association with the Engineering Council and is accredited by them. An accredited MEng degree in an engineering discipline is the foundation qualification for those wishing to become Chartered Engineers. *Engineering Council*, http://www.engc.org.uk/engc/1/index.html

3.69 Another form of longer course is the 'sandwich course', which involves a year-long placement in employment as part of the course. It is possible that the requirement for students on sandwich courses to pay half of their normal tuition fee[129] for the year is disincentivising the take-up of these courses. The Review is aware that a number of students currently take years out of study in preference to a formal course placement to avoid paying tuition fees.

3.70 Over 60 per cent of students supplement their income through part-time work. It is recognised that the number of contact hours involved in science and engineering subjects greatly exceeds those expected of most arts and humanities and some business courses. The difference is mostly due to time expected of SET students in laboratory work. This factor reduces a student's capacity to find part-time employment, which may act to deter some potential students from choosing SET courses – particularly those from low income or otherwise disadvantaged backgrounds.

3.71 The best evidence available to the Review[130,131,132] did not indicate that student debt deters people from participating in higher education, although it is clear that it is a source of much concern to students. The Review has also found no concrete evidence that prospective debt deters significant numbers of students from undertaking a four-year as opposed to a three-year degree. Rather, debt mainly becomes a deterrent when graduates consider postgraduate study. However, it is possible that there is a link between the decline in the number of chemistry and physics graduates and the proportion of four-year courses in these subjects. The Government should monitor this situation to ensure that it does not become a problem.

[129] The fees pay for the student's continued support by the institution and broader costs of the course, not just 'tuition'. In some cases the need for this funding and what it is spent on do not appear to have been explained to students, who often resent paying a 'tuition fee' when they receive little tuition in the year out from the course. In other cases the HEI may not have provided sufficient support to its sandwich-year students.

[130] *Changing student finances: income, expenditure and the take-up of student loans among full- and part-time higher education students in 1998/9*, C Callender and M Kemp, South Bank University, December 2000.

[131] *Student living report 2002*, commissioned by Unite and conducted by MORI, January 2002.

[132] *HEFCE 01/62*, October 2001.

Recommendation 3.5: Undergraduate student funding

While student debt does not in general appear to be deterring potential students from undergraduate education, at the margin some undergraduates may be deterred from science and engineering courses, as they involve longer hours than other courses and as a result students find it more difficult to supplement their income by working part-time. In order for this not to deter the most disadvantaged students from studying science and engineering (and other courses with long 'contact hours'), and to assist with widening participation, the Review recommends that the Government (through its guidance to HEIs) should ensure that the Access Funds and Hardship Funds adequately provide for students on courses involving a high number of contact hours. The Review recommends that additional funding should be provided to accommodate this, and that HEFCE monitor the targeting of this additional funding to ensure it reaches those most in need.

The Review also recommends that the Government closely monitor the impact that an additional year of student debt has on students' choices of course, to ensure that the student funding system at undergraduate level is not discouraging students from studying (the longer) physical science and engineering courses.

The careers of SET graduates

Why work in SET?

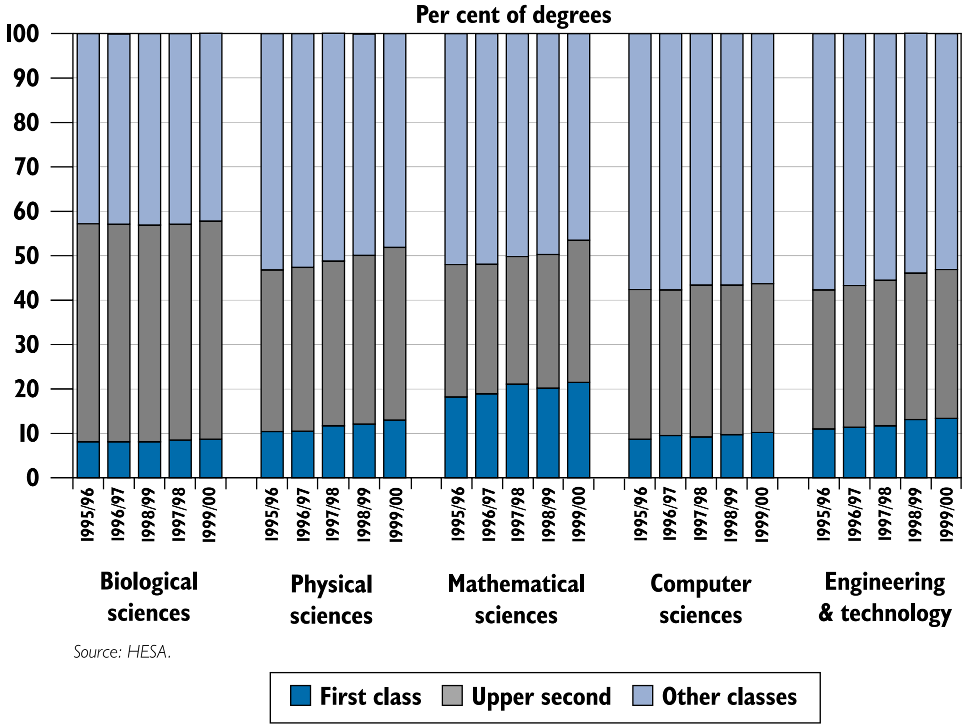
3.72 According to a recent report[133] for the Office for Science and Technology, men and women holding SET degrees had initially chosen to work in SET occupations because they had enjoyed their studies. Those that continued to work in these occupations, preferred the work because they found the work was varied, they enjoyed problem solving, they were not office bound and there were travel opportunities on offer. Those who disliked working in SET occupations found that their job was boring and repetitive, and they had little control over what they did and how they did it. They complained about poor working environments with little human interaction, not being able to see immediate results from their work, and about low rates of pay.

The quality of SET graduates

3.73 The careers open to SET students depend on their subject knowledge and ability (often measured by their degree class), and their skills. The small overall decrease in the number of physical science and mathematics students between 1995 and 2000 coincides with slight rises in the proportion of first class degrees and 2:1s awarded in these subjects, as shown in Figure 3.7 below. A similar effect is seen in engineering and technology. In the biological sciences, however, the proportion of first class and upper second class degrees awarded has stayed fairly constant. In computer science, the proportion of first class computer science degrees increased slightly but the proportion of 2:1s awarded remained constant.

[133] *Maximising Returns to science, engineering and technology careers*, prepared for the Office of Science and Technology, by People Science & Policy Ltd & Institute for Employment Research (University of Warwick), January 2002.

Figure 3.7: Number of SET undergraduate degrees by classification and subject over time



Source: HESA.

3.74 These patterns seem to indicate that the quality of SET graduates is stable or slowly improving. One interpretation is that the reduction in student numbers in some subjects comes from fewer weak students applying for these 'hard' subjects. The Review is aware that the A-level points scores of students with A-levels in maths, science and technology compares well with those in other disciplines. In 2000, both the maths and science intake had a higher points score than average (23.7 and 20.5 respectively, compared to an average of 18.8). Technology was slightly below average (17.6).[134]

3.75 However, employers are concerned about the application of graduates' skills and knowledge in the workplace, so a definition of quality is needed which rests on students' practical experience as well as their exam results. Employers' skills requirements and the career choices available to SET graduates are discussed below.

[134] *Scientists and Engineers: A study paper on the flow of students with A levels into full time undergraduate courses of study,* Council for Science and Technology, (to be published April 2002).

Employability of graduates

3.76 Final year undergraduates appear to show interest in the employment routes followed by their predecessors.[135] Many seem increasingly motivated by financial reward, and look to employers offering the highest starting salaries, such as finance, banking and consultancy, rather than to technological and engineering industries. Most of the highest paying graduate jobs in these sectors require a good quality degree (2:1 at least) and may ask graduates to demonstrate specific skills such as business awareness and analytical skills. Employers' judgements are frequently based on the reputation of the HEI awarding the degree, and the title and 'reputation' of the degree itself. Demand for SET graduates, including competition from non-R&D employers, and SET graduate pay are explored further in Chapter 6.

3.77 Recent graduate surveys conducted by both The Guardian and The Times show graduates' salary expectations have increased in recent years and tend to be unrealistically high,[136] although these studies do not indicate expectations specifically for SET graduates. Expectations about increases in salary after five years also appear unrealistic when compared to the actual situation indicated in Figure 6.4 in Chapter 6, other than for jobs in financial services and some other service industries.

3.78 These high expectations might explain why SET graduates motivated by money choose to use their skills in non-R&D related careers. For similar reasons, it might explain why some of the most able SET graduates choose not to go onto postgraduate study. Another factor that might deter postgraduate study is the incidence of students receiving job offers in advance of the completion of their degree, particularly students on courses that offer industrial placements. This is most common in computer science and related subjects, where young people with the right skills have been in high demand.

Employers' skills requirements

3.79 When recruiting SET graduates for scientific jobs, 'technical/practical knowledge' and 'academic skills and knowledge/attainment' are sometimes more important to employers than candidates' personal qualities and inter-personal skills. Nevertheless, the latter are still sought after and employers often regard SET graduates as being poor at applying and developing the knowledge and the skills that they have acquired (particularly practical skills).

3.80 Recruiters interviewed in the Mason report's 1998 survey[137] said that new graduates' jobs had in recent years become more complex and demanding. It is important that these changes and the skills required to respond to them

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[135] *The labour market for engineering, science and IT graduates: are there mismatches between supply and demand?,* G Mason, National Institute of Economic and Social Research, March 1999.

[136] *Grad facts 2000,* The Guardian, 2000 and *The UK Graduate Career Survey 2001,* The Times, 2001.

[137] *The labour market for engineering science and IT graduates: are there mismatches between supply and demand?,* G Mason, National Institute of Economic and Social Research, March 1999.

are reflected in the careers advice given to students. Employers interviewed for the Mason report[138] put lack of appropriate work experience highest on their list of poor qualities in graduate job applicants. In particular, graduates are expected to take responsibility and add value at a much earlier stage than previously. This is particularly important for SMEs.

3.81 A quality often sought by employers is 'commercial awareness'. There is a limit to how effectively this can be taught in HEIs, particularly by staff with limited commercial experience. The twelve Science Enterprise Centres in universities around the UK (ten in England and one each in Scotland and Northern Ireland) have an important role in educating HE staff and students in enterprise and entrepreneurship.

The role of careers advice in graduate career decisions

3.82 Chapter 2 explored the need for better advice at school about SET careers, which impacts on A-level combinations and in turn on degree course options. Students do not always enter higher education with clear career goals, often choosing their degree courses on the basis of the subjects they enjoyed and excelled in at school,[139] and careers advice is therefore important at university level too.

3.83 Students report receiving the best advice about skills required by industry, careers options, and areas of future growth from lecturers with industrial experience. Students welcomed discussions with lecturers about their industrial experiences, and the relevance of these in academia. A constraint on this is that currently there are not enough opportunities for industrial exchanges for academic staff. Industrialists could also benefit from experience of the way that universities work, and the current themes of their research. Industrial exchanges, therefore, promote links between universities and businesses, as well as benefiting students.

3.84 University careers services also play an important role in advising on future careers and postgraduate education. The Mason report indicated that those undergraduates who sought out university careers services found them helpful. However, careers services can be insufficiently pro-active, and fail to reach many students who do not realise that they need advice. A code of practice for HE careers services has been published by the Quality Assurance Agency for Higher Education.[140]

3.85 The Harris Report[141] noted that the prime function of university careers services "is to help the institution produce better-informed students who are self-reliant, able to plan and manage their own learning and have sound career management skills". It also said that "Clarity of mission, lines of accountability,

[138] *The labour market for engineering, science and IT graduates: are there mismatches between supply and demand?*, G Mason, National Institute of Economic and Social Research, March 1999.

[139] *Great Expectations – the new diversity of graduate skills and aspirations*, K Purcell and J Pitcher, Institute for Employment Research, University of Warwick, October 1996.

[140] *Guidance on preparing students for careers*, Press notice – www.qaa.ac.uk, 23 January 2001.

[141] *Developing Modern higher Education Careers Services*, Sir M Harris, Manchester University, *Higher Education Careers Services Review report for DfES*, December 2000.

performance measurement and adequate resource allocation need to underpin every Higher Education Careers Service". In his report, Sir Martin Harris noted that students "have very different experiences of Careers Services" and that "resources devoted to these services varied considerably across institutions". Awareness about how to use careers services varied, and was low among socially disadvantaged groups, particular subject groups and mature learners. Many students obtained advice too late to influence study choices or undertake development activities.

3.86 This Review is concerned to see driven forward a number of recommendations from the Harris report, alongside the improvements to careers advice in schools recommended in Chapter 2:

- HEIs should develop meaningful links with businesses that complement work done by careers services, such as the offer of work placements;
- careers services should develop sound working relationships with Connexions Service Partnerships, so that young people (starting at 14) are able to recognise the career implications of their course choices; and
- careers services should review their links with employers and organisations such as the Small Business Service to ensure that academic departments are assisted in meeting needs and have contacts in new areas and areas where graduates are under-represented.

3.87 SET students should receive up-to-date advice on the career options open to them (particularly opportunities in R&D and the benefit of postgraduate study). Students also need advice on – and opportunities through appropriate courses to acquire – the generic skills needed to prepare them for work. Universities and businesses, therefore, need to work together more closely in order to best develop the skills that both employers need. Students themselves need to take responsibility for ensuring that, in the light of improved information, they do what they can to acquire the skills that will enhance their employability.

Recommendation 3.6: University careers advisory services

The Review welcomes the recommendations of the Harris report on improving university careers advisory services. It is important that science and engineering students have accurate, up-to-date careers advice on the rewards and range of opportunities available to them (particularly opportunities in research and development). In particular, the Review endorses the recommendations in his report aimed at improving the links between careers advisory services and businesses, particularly small businesses, which will require action by both HEIs and by businesses.

4 POSTGRADUATE EDUCATION

Summary of issues

The decline in A-level and undergraduate numbers in mathematics, the physical sciences and engineering has coincided with falls in the number of PhDs awarded in these subjects. The number of PhDs awarded in computer science has also fallen from its 1994 level despite higher intakes at undergraduate level.

There are also concerns that the quality of postgraduate student intake and output is declining. In some subjects this can been seen in lower proportions of PhD students with upper second and first class undergraduate degrees. PhD students are also seen to be poorly prepared for work in either academia or business. Over time these trends will reduce the ability of the UK to continue to carry out world class R&D.

The chapter first examines the number and calibre of students taking up postgraduate study in science and engineering. These are affected by the issues in schools, colleges and undergraduate education that were explored in Chapters 2 and 3. However, there are additional problems with postgraduate study that make it an unattractive option for able graduates in science and engineering subjects. The Review makes recommendations to overcome this by addressing:

- the fact that **PhD study is financially unattractive** in the short term. The gap between PhD stipends and the starting salaries of able graduates has increased dramatically over the last 25-30 years and more recently this is exacerbated by increasing levels of average undergraduate debt. Furthermore, careers in both academic and industrial research for which scientific PhDs are required are less financially attractive than some other options; and
- the problem that skills acquired by PhD graduates do not serve their long-term needs. Currently, **PhDs do not prepare people adequately for careers in business or academia**. In particular, there is insufficient access to training in interpersonal and communication skills, management and commercial awareness. This can be improved in many ways, including provision of more funded 4-year PhDs.

Postgraduate courses and qualifications

4.1 Scientific researchers almost invariably begin their research training in higher education. Some may enter R&D employment at the graduate level, others after a Masters degree, PhD or post-doctoral experience. Not all development work requires extensive research training, but often the research elements of R&D in academia and in industry require research experience that is generally gained only through a PhD.

4.2 Postgraduate study is therefore fundamental to the development of the highest level of science and engineering skills. It develops specialist knowledge and, particularly at the PhD level, trains students in the techniques and methods of scientific research. The majority of the UK's future scientific researchers will need postgraduate qualifications, as will those in other countries. Any reduction in the supply and quality of scientists and engineers trained to this level is therefore of primary importance to the UK economy.

4.3 After analysing the declining numbers of postgraduate science and engineering PhDs awarded, this chapter explores the reasons for this trend and makes recommendations to ensure that:

- postgraduate study is made attractive to the most able graduates. (in particular the chapter considers the case for increasing the level of the PhD stipend, and the length of PhDs);
- PhDs are producing people with the necessary balance of skills to conduct high quality research and development in industry, universities and the public sector. Currently, insufficient emphasis is placed on transferable skills.

4.4 Some of the Review's conclusions are mirrored in two recent reports that examine the current situation in the UK regarding postgraduate students: a report on doctoral research students in engineering by the Royal Academy of Engineering[142] and (outside the scope of this Review) the British Academy's review of graduate studies in the humanities and social sciences.[143]

Postgraduate qualifications

4.5 Postgraduate qualifications essentially divide into two categories, taught degrees (MSc) and research degrees (MPhil, PhD). However the MRes is a hybrid of the two, and newer doctoral programmes such as the EngD contain significant taught elements (see the box on postgraduate qualifications below for more detail). Taught qualifications can offer valuable training in specialist areas of science and engineering, but do not provide research training and were rarely mentioned by respondents to the Review's consultation. In the context of this Review, therefore, the MSc is not explicitly considered. The MRes is a relatively new qualification, and again did not attract significant comment in the consultation process. The focus of this Review (and of responses to the consultation) has therefore been on research degrees, particularly the PhD.

4.6 Postgraduate education generally requires a first degree at a high level – usually a 2:1 or a 1st class honours degree for a PhD (usually over three years) or a 2:2 for a Masters course which may either be taught or research-based (usually over one year). Many students often go on to postgraduate study immediately following their first degree, although a proportion return to academic study having spent time in business. This is particularly the case for taught courses like the MSc.

[142] *Doctoral Level Research Students in Engineering: A national concern*, Royal Academy of Engineering, February 2002.

[143] *Review of Graduate Studies in the Humanities and Social Sciences*, The British Academy, 2001.

Postgraduate qualifications

Master of Science (MSc)

The MSc is a one-year full time taught postgraduate course (generally also available part-time) that comprises a combination of taught modules, independent study, guided study programmes, lecture courses and project work. An MSc qualification indicates in-depth study in a subject beyond undergraduate level.

Master of Research (MRes)

This is a relatively new one year full-time course leading to a Master of Research (MRes) degree. Its purpose is to offer high quality postgraduate training in the methods and practice of research and in relevant transferable skills that are not normally offered in MSc courses. The MRes degree is intended to serve as a qualification for entry to a research career in industry or as an enhanced route to a PhD through further research. Each MRes course is structured to include a significant research component (comprising at least 50 per cent of the working year) and a series of supporting taught courses.

Master of Philosophy (MPhil)

The MPhil is a one or two year full time research course (2-3 years part-time). MPhil students typically join a research group, carry out a research project, and attend lecture courses and seminars appropriate to their topic. They write a dissertation on their research and have an oral examination at the end of the year. In some subjects – particularly those with 3-year undergraduate qualifications, and so mostly outside SET – an MPhil degree or equivalent is a necessary qualification for would-be PhD students.

Doctor of Philosophy (PhD, DPhil)

The PhD is usually a three year full time course (around five years part-time) involving training in and practice of original academic research. The student carries out and writes up a research project, which is examined by thesis and by an oral examination (the *viva*). In some HEIs the abbreviation DPhil is used; this report uses PhD to mean both.

Engineering Doctorate (EngD, DEng)

The Engineering Doctorate is a four-year postgraduate award intended for research engineers who aspire to managerial positions in industry. The core of the degree is the solution of one or more significant and challenging engineering problems within an industrial context, which includes taking factors such as financial constraints, timescales and personnel management into account.

The majority of EngD project work must be carried out within a sponsoring organisation conducting research in the UK. Supervision of the research is jointly between an industrial manager and an academic. Packages of training courses are tailored to the needs of individual candidates in order to develop a wide range of competencies in engineering business management, as well as specialist technical subjects. This taught component is assessed and forms an integral part of the degree.

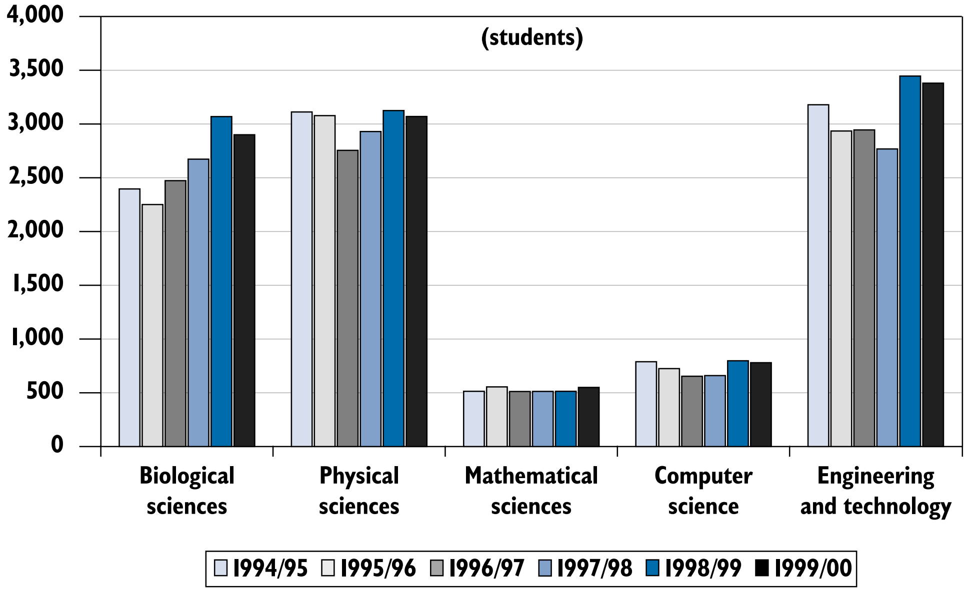
4.7 Funding for Masters degrees is often by the student, although some institutional support is available, and the Research Councils sponsor some places on MSc courses[144]. PhD funding comes from a variety of sources, including institutional (university) funds, industrial and charitable sponsors and the Research Councils, which support around a third of SET PhD students. Relatively few UK PhD students in SET self-fund.

The supply of postgraduate students

4.8 Each year, around 10,000 students enter science and engineering PhDs in the UK, of whom about a sixth are part-time. The UK produces over 7,000 PhD graduates a year in SET; exact figures are difficult to establish as a number of PhD students become 'dormant' (cease to be students at the HEI) before the eventual award of their PhD, and the proportion of these who are SET students is unknown.[145] Of those 6,000 gaining PhDs in SET subjects in 1999/2000 whose origins are recorded, 67 per cent are UK residents, 10 per cent from other EU countries and 23 per cent from outside the EU.

4.9 The number of doctorates awarded in the UK in all subjects increased by about 18 per cent between academic years 1995/96 and 1999/2000. The biggest growth areas for UK students were social studies and law (an 80 per cent increase in each), creative arts (over 110 per cent growth), and education and leisure (130 per cent growth). Over the same period, UK-domiciled students gained around 600 additional doctorates each year in medical,

Figure 4.1: Number of first year postgraduates (full & part-time), 1994/95 to 1999/00



Source: HESA.

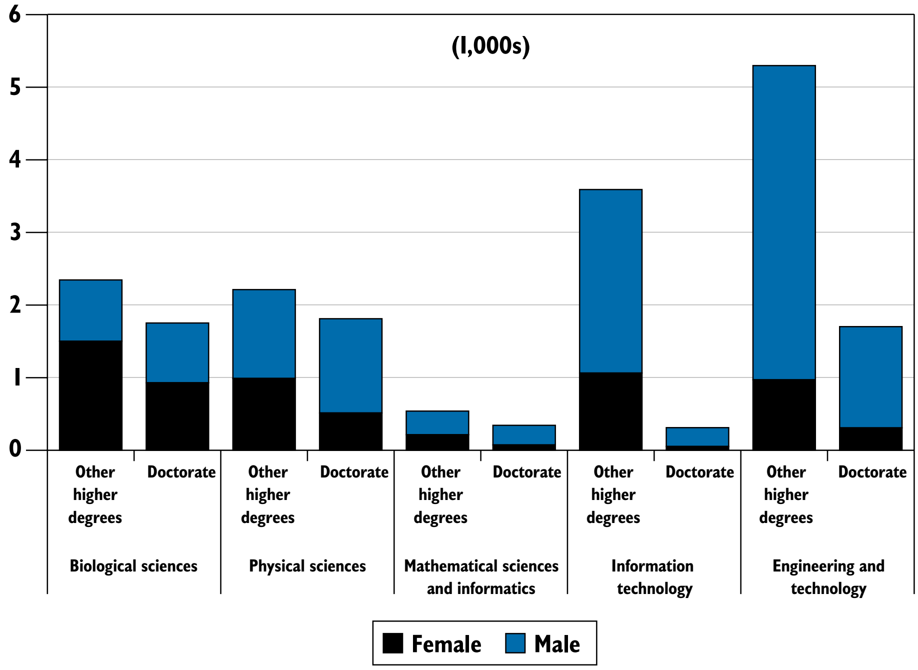
[144] Historically, around 2500 Masters course places each year, the vast majority sponsored by EPSRC.
[145] These figures are taken from *Students in Higher Education Institutions 1999/2000,* HESA.

biological and related subjects. However, the number of doctorates awarded to UK-domiciled students in the physical sciences fell by 9 per cent between 1995/96 and 1999/2000.

4.10 Figure 4.1 shows improvements in recruitment to postgraduate study (predominantly PhDs[146]) at the end of the 1990s. These coincide with a significant increase in PhD stipends in 1998/99 (up 22 per cent to £6,455 in summer 1998), although numbers fall again in 1999/2000. A similar pattern to physical sciences is seen for computer science, for which the number of PhDs awarded has also fallen from its 1994 level, though again postgraduate recruitment has recovered after a dip in 1996/97.

4.11 Figure 4.2 illustrates that in physical and biological sciences around 40 per cent of all postgraduates are PhD students, whereas non-doctoral higher degrees are the most common postgraduate qualifications in computer science. Figure 4.3 illustrates a generally upward trend in women's participation in SET doctoral study, to over 50 per cent in the case of biological science. Although absolute levels of women's participation in SET subjects are low (15-30 per cent outside biological sciences), they are approximately in proportion to the percentage of women entering SET undergraduate courses three or four years earlier. Indeed, a higher proportion of women graduates than male graduates in engineering enter PhDs.

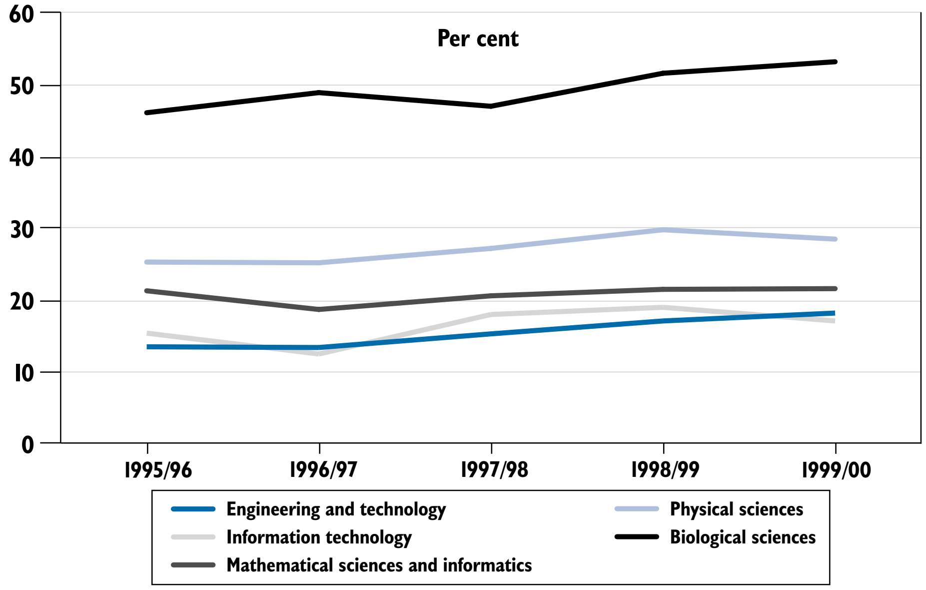
Figure 4.2: Gender and subject of qualifying postgraduates, 1999/00



Source: HESA.

[146] In many universities new students on PhD grants are initially registered for an MPhil or other postgraduate research qualification then transfer to a PhD course after a probationary period, and so cannot be distinguished from non-PhD students on MPhil courses.

Figure 4.3: Proportion of doctorates awarded to women, 1995/96 to 1999/00



Source: HESA.

The role of the Research Councils in PhD supply

4.12 The major influence on PhD availability and design are the Research Councils, which together fund around a third of the UK's PhDs in SET (around 4,000 across the Research Councils). The proportion of PhDs funded by the Research Councils varies greatly by subject area: over 45 per cent of physics PhDs and a third of maths PhDs are sponsored by a Research Council, whereas it is fewer than 20 per cent of PhDs in life sciences and electrical & electronic engineering and just over 10 per cent of PhDs in civil engineering. The principal funder of research activity is 'other' (which includes funding provided by the university), with 5-15 per cent of students funded as fee-paying overseas students and another 5-15 per cent funded by industry[147]. Around 650 PhD studentships are collaborative (CASE) awards involving an industrial sponsor with a track record in research; under EPSRC's Industrial CASE scheme (300 awards), the company defines the research topic, chooses a partner university, and may influence the choice of student.

4.13 The Quinquennial Review of the Research Councils published in November 2001 concluded that the Research Councils have a critical role to play in ensuring the supply of high-quality researchers in the UK, both by supporting postgraduate research training, and in fostering young scientists' early careers through fellowship schemes. The key recommendation of the Quinquennial Review concerning postgraduate training and research was that:

[147] Source: EPSRC data to support the 2001 Balance of Programme exercise, from www.epsrc.ac.uk

"The Research Councils, collectively and individually, should give greater attention to postgraduate training and postdoctoral research career support, taking note of the findings of the 'Roberts Review' in due course."

4.14 The Review makes its recommendations on postgraduates and on contract research staff (Chapter 5) in this context. Although the majority of PhD students are trained in HEIs, the Review intends these recommendations to apply in Public Sector Research Establishments and other non-HEIs in which PhD students work and learn.

The attractiveness of postgraduate study

4.15 Fluctuations in the numbers of SET postgraduates, particularly doctoral (PhD) candidates, have led to concerns by respondents to the Review that postgraduate education is becoming less attractive. A recent survey of postgraduate study intentions[148] shows that the long-term career goals of those graduates considering doctoral study are often to work as scientists and researchers, in academia and in industry. Reductions in the supply of PhD students are therefore likely to indicate reductions in the number of people wishing to enter these positions.

4.16 According to the postgraduate study intentions survey, 39 per cent of final year undergraduates across all subjects intended to pursue some form of postgraduate study, and another 28 per cent considered that they might. 30 per cent definitely would not pursue further study. Only 3 per cent had not considered it at all, indicating that promotion of postgraduate study is widespread within the higher education system. The survey found that undergraduates seem to be starting to plan their futures earlier, which may require changes in how universities market their postgraduate courses.

4.17 The major influences on whether an individual studies for a PhD or other postgraduate qualification are:

- the immediate financial reward to the individual, both in absolute terms and relative to other jobs and to the level of any debts the individual has;
- the perceived long-term financial and career effects of postgraduate study, including the attractiveness, or otherwise, of the careers in research and development for which a PhD is a prerequisite; and
- the non-financial attractiveness of postgraduate study versus other employment to the individual.

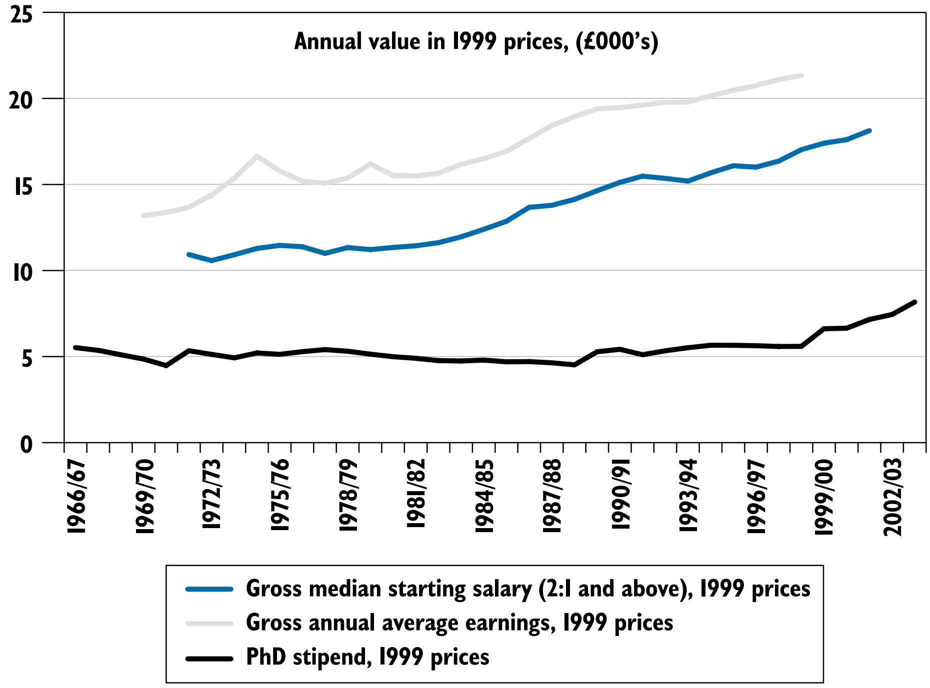
These issues are considered below in more detail.

[148] *Report of the Findings of the 2000/2001 Survey of Postgraduate Study Intentions*, M Phillips, University of Sheffield on behalf of the Office of Science and Technology (OST), 2001.

Short-term financial considerations in PhD study

4.18 PhD stipends are increasingly uncompetitive with the salaries of graduates, particularly those of able graduates in the physical sciences, mathematics, engineering and computer science. Figure 4.4 shows that in the 20 years from 1971/72, the PhD stipend fell by 4.5 per cent in real terms, while starting salaries for graduates with a 2:1 and above rose by 42 per cent. The recent increases in Research Council PhD stipends from £6,800 in 2000/01 to £7,500 in 2001/02, £8,000 in 2002/03 and £9,000 in 2003/04 announced in the *Excellence and Opportunity* White Paper (DTI, June 2000) have prevented the differential between stipends and salaries from increasing.

Figure 4.4: Comparison of PhD stipend, graduate starting salary and national average salary, 1966/67 to 2002/03



Note: 1998/99 figure was increased in summer 1998 following the Comprehensive Spending Review from the previously announced figure of £5455 to £6455

4.19 PhD stipends are currently comparable to the lowest incomes for full-time employment. The National Minimum Wage (NMW) is currently £4.10 for workers aged 22 or over. Employment at the NMW for 40 hours per week, 52 weeks per year would net £8,728 gross, or £7,477 after income tax and National Insurance (NI) contributions. This is approximately equal to the current level of PhD stipends (£7,500 in 2001–2002), which are not taxable. This sends a signal to prospective students that undertaking a PhD is likely to result in a rather Spartan existence.

4.20 PhD students typically undertake some small-group teaching or laboratory demonstrating, which in addition to developing transferable skills and improving the variety of PhD study also brings in income.[149] A student doing the EPSRC recommended maximum of 6 hours per week for 30 weeks per year (the work is generally with undergraduates who are not taught year-round) at £10 per hour would earn £1,800 per year, which is below income tax and National Insurance thresholds. A typical PhD student on a Research Council grant therefore earns around £9,300 p.a. net of tax; the median graduate salary of *c.* £17,500 (for those with a 2:1 or above) is worth around £13,500 net of tax. These comparisons are summarised in Table 4.1 below.

Table 4.1: Comparison of PhD stipend levels with available salaries

Annual income level	Net of tax & NI £ p.a.
National Minimum Wage (40 hours/week, 52 weeks/year)	7,477
PhD stipend 2001-02 (not taxable)	7,500
PhD stipend 2002-03 (not taxable)	8,000
PhD stipend 2003-04 (not taxable), minimum[150]	9,000
Mean graduate expected salary in 2000 (first job)	12,285
Wellcome Trust PhD stipend (bioscience, outside London, Year 1)	13,085
Median starting salaries of graduates with 2:1 or above	13,442
High calibre graduate job (e.g. consulting) starting salary	20,600

** assumes a single person under 65 in employment contracted into National Insurance financial year 2001/2.*

Source: Compiled from data quoted elsewhere in this report; estimate of high calibre graduate job income based on figure quoted in graduate recruitment brochure.

4.21 The growing gap between PhD stipends and graduate salaries, particularly for graduates in the more numerate and IT-intensive disciplines, is acting as a growing disincentive to PhD study. This is exacerbated by students' undergraduate debt, which is a major, and increasingly important, deterrent to postgraduate study.[151] The existence of undergraduate debt also seems to exert a psychological influence on graduates' career choices over and above the difficulties of repaying debt on a PhD stipend. (It should be noted that PhD students generally do not have to repay their student loans until after they complete their PhD programme.)

4.22 It is not uncommon for graduates to have debts of £10,000 or more on graduation, and – as noted in Chapter 3 – the average level of debt is increasing. In the 2001 Sheffield/OST survey of postgraduate study intentions,[152] 65 per cent of all graduates who had decided against further study reported debt to be a determining factor in the decision, and three quarters of those interested in postgraduate study were concerned about debt. The desire to enter employment immediately, which is often linked to

[149] Postgraduates' participation in these activities, and in the teaching assistants programme recommended in Chapter 2, should continue to be encouraged by institutions and must be supported by suitable training.

[150] Some Research Councils such as MRC pay more than this minimum rate; other sponsors of PhDs such as universities may pay less, though a few such as the Wellcome Trust pay more.

[151] Comparison of the 2001 *Survey of Postgraduate Study Intentions* results with the previous year's survey; see also the British Academy's *Review of Graduate Studies in the Humanities and Social Sciences.*

[152] *Report of the Findings of the 2000/2001 Survey of Postgraduate Study Intentions*, M Phillips, University of Sheffield on behalf of the Office of Science and Technology (OST), 2001.

the desire to clear debt, was also an important factor in undergraduate career choices for 76 per cent of those who had decided against postgraduate study.

4.23 The effect of debt, and particularly high-interest debt on credit cards, extends beyond its immediate financial implications in terms of interest payments. Although students do not seem to be particularly sensitive to accumulating debt (for example, many use student loans to achieve lifestyle objectives) this appears to go hand in hand with an intention and desire to pay off this debt on graduation. Graduates who have previously borrowed to finance lifestyle aspirations as undergraduates are unlikely (and probably unable) to do so throughout a PhD, particularly as overrunning the funding period will incur more debt.

4.24 The majority of PhD students do not have to start paying off student loan debt while studying, since they do not have taxable incomes over £10,000; the exceptions are PhD students employed as research assistants (who therefore earn more than the typical PhD student). However, graduates wishing to clear their debts immediately still see this postponed debt[153] as a problem. It is worth noting that a number of graduate employers pay 'golden hellos' of up to about £10,000 to help attract new graduates, which do not appear in the salary figures given in Figure 4.4. This may be valued psychologically by graduates (representing freedom from debt) as well as for its financial value, and may therefore exert a significant effect on some graduates' career choices.

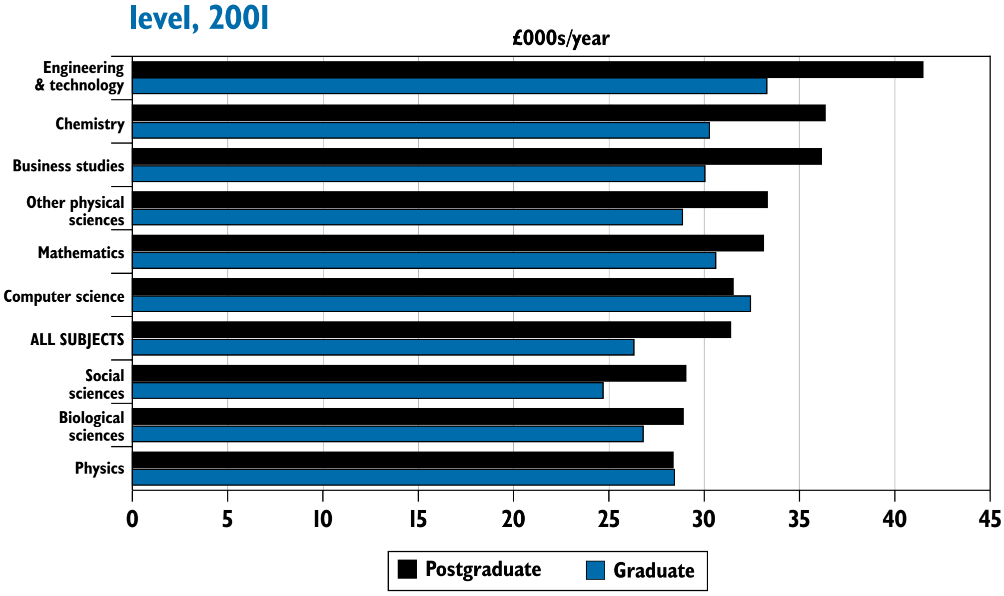
Long-term benefits of postgraduate study

4.25 The divergence between PhD stipend levels and graduate salaries, and the effect of growing undergraduate debt, are acting as disincentives to postgraduate study. However, this should to some extent be offset by the good long-term salary prospects of postgraduates.

4.26 The average salaries of SET postgraduates almost invariably exceed those of non-postgraduates, as illustrated in Figure 4.5 below. To some extent this represents the premium paid to higher-ability graduates, from whom postgraduates are generally drawn. The evidence is that a postgraduate qualification will tend to improve, rather than damage, career and earnings prospects, in the long term.

[153] at 0% real interest (the debt increases in line with inflation).

Figure 4.5: Gross annual pay in main job by discipline and level, 2001



Source: Labour Force Survey, March 2001.

4.27 The exceptions to this trend are computer science and physics, in which graduate and postgraduate average salaries are virtually identical. This is consistent with reports to the Review that the IT industry generally does not value computing postgraduates over graduates (in other words, does not pay a salary premium to postgraduates) and also has a high demand for skilled (graduate) labour.

4.28 Some career opportunities in business R&D and in academic research are open only to PhDs. Some undergraduates are disincentivised from postgraduate study because these careers are often reported to be poorly-paid and insecure, with poor working conditions. Although these jobs require a PhD, research students interviewed by the Review felt that these 'R&D employers' did not value postgraduates as much as other high-quality employers.[154] The general impression among postgraduates interviewed by the Review Team was that research jobs were unattractive for financial reasons, although a number still wished to pursue them for non-financial reasons, generally personal interest. The issue of career attractiveness is covered in more detail in Chapter 5 (employment in universities) and Chapter 6.

4.29 The long-term benefits of postgraduate study are therefore a potential motivator for students to do a PhD. Although starting salaries for SET postgraduates are not particularly high, and there are issues around the attractiveness of research jobs in both HE and business, postgraduates' long-term earnings potential is good. However, this is more than countered by the short-term disincentives to PhD study posed by low stipends and undergraduate debt. Furthermore, the lack of an initial salary premium for PhDs in many R&D jobs masks the potentially higher salaries which may be available later on.

[154] A view reported in *Doctoral Level Research Students in Engineering: A national concern*, Royal Academy of Engineering, February 2002.

Non-financial factors affecting the attractiveness of postgraduate study

4.30 The Review's discussions with current and recent PhD students have indicated that PhD courses attract highly able potential researchers who value the opportunity to carry out basic research, very often because of a strong interest in the subject and sometimes (again based on the Review's discussions with research students) due to an unwillingness to make career or employment choices in the run-up to graduation.

4.31 Careers advice plays a role in postgraduate recruitment, as noted in Chapter 3: over a quarter of those definitely intending to pursue postgraduate studies cited careers advice as a factor in this decision. If graduates are not aware of the career opportunities open to them as a direct result of attaining further qualifications, then they will be less likely to consider this option. Academic tutors are an even stronger influence on students: in the Sheffield/OST survey[152] of postgraduate study intentions, 57 per cent of students who had definitely decided on postgraduate study (of whom three quarters wanted to be PhD students) were influenced by their tutor. The immersion of SET undergraduates in an environment which values and respects postgraduates and the fostering of positive attitudes to research and to knowledge creation also aid PhD recruitment.

4.32 HEIs currently rely on such non-financial factors (essentially, the preferences of individual students) to attract students to PhD study. This tends to attract individuals with a strong interest in the research topic and the other non-financial aspects of a PhD and/or those who place the least value on the non-financial aspects of employment (including work environment and commercial ethos). This may act to conserve academic quality of PhD students at the expense of quality as perceived by business.

The current attractiveness of PhD study

4.33 The low stipend and low starting salaries for PhD holders mean that PhD study is increasingly unattractive to graduates. Many university departments report difficulty in finding sufficient numbers of PhD students – particularly UK PhD students – in certain disciplines such as engineering[155] and computer science. Improvement to PhD stipend levels is needed to ensure the UK's supply of scientists and engineers is maintained.[156]

4.34 In addition to problems in the quantity of PhD students in some disciplines, there are complaints from employers – particularly in industry – that the *quality* of PhD students is too low and/or declining. This is a particular criticism of their broader interpersonal and management skills, although some concern has been expressed both about the technical skills and the creativity of many

[155] *Doctoral Level Research Students in Engineering: A national concern*, Royal Academy of Engineering, February 2002.

[156] This was also recommended in *The Funding of Higher Education*, Council for Industry and Higher Education, December 2001, for example.

PhD graduates. The chapter therefore considers these issues of *quality* and makes recommendations to improve both the quality and quantity of PhD students.

The quality of PhD entrants

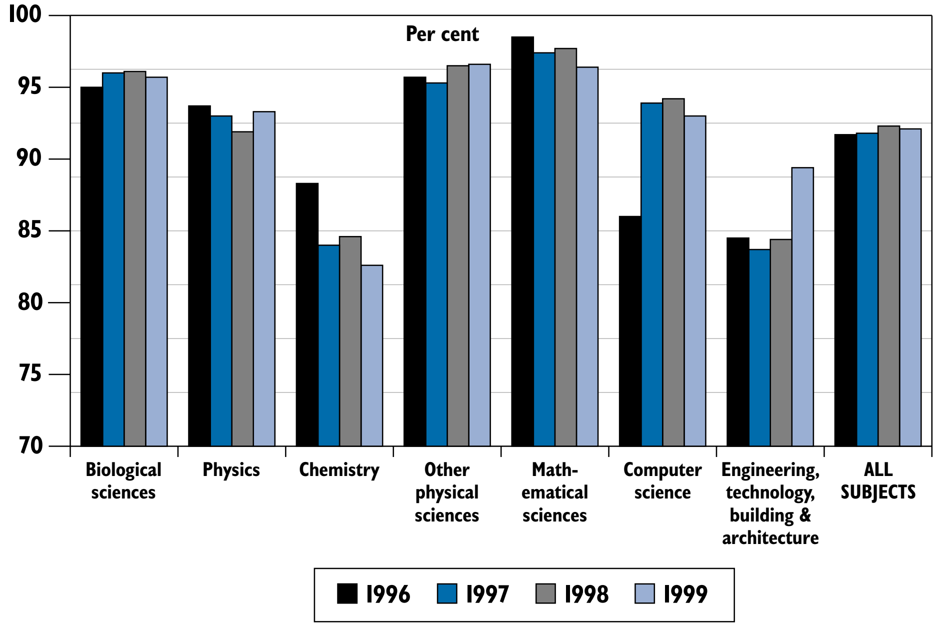
4.35 A particular concern of many respondents to the Review was the quality of PhD students, both at the commencement of their study and on completion of it. The overall quality of undergraduate education in science and engineering was discussed in the previous chapter. The quality of the PhD student intake and the factors affecting this are explored below, before turning to issues of the quality of PhD training and PhD holders.

4.36 The most easily obtained measures of the quality of those undergraduates going on to study for a PhD are their A-level points scores and degree classes. These are measures of academic rather than employer definitions of quality, although there is some correlation between the two.

4.37 Over the period 1996-2000, an increasing proportion of those beginning PhD study had 24+ A-level points. However, this increase needs to be understood in the context of recent substantial rises in the proportion of pupils achieving grades A and B in maths, physics, chemistry and biology A-level. As discussed in Chapter 3, many HE staff therefore believe that A-level points scores are a poor predictor of student quality at undergraduate and, by extension, postgraduate level. The Review therefore finds it difficult to assess whether A-level points scores show an improvement in PhD entrant quality.

4.38 By contrast, there is no significant general trend in the degree class of those entering PhDs, although as Figure 4.6 shows there are some subject-related trends. The proportion of PhD entrants with a First or 2:1 has remained largely unchanged in most SET subjects: there has been a very slight upward trend overall (driven by increases in computer science and engineering); a noticeable downward trend in chemistry; and a slight decline in maths. These trends need to be seen in the light of the slight increases in the proportions of first class degrees and 2:1s gained in most SET subjects shown in Figure 3.7 in Chapter 3. Given that there will be random fluctuations in the underlying data, the only reasonably firm conclusion to be drawn from this degree class information is that the quality of students beginning PhDs in chemistry seems to have declined over the last few years.

Figure 4.6: Per cent of PhD entrants with a 2:1 or First, 1996 to 1999



Source: Unpublished HEFCE analysis of HESA data.

The case for additional incentives to undertake PhDs

4.39 If the quality of students entering PhD programmes is not to decrease, PhD stipends must not fall further behind the expectations of highly able graduates. Given the increasing importance of non-salary elements of remuneration (golden hellos, travel opportunities) and the growing levels and effect of undergraduate student debt in choosing employment, there is a strong case that the gap needs to be closed even to maintain quality of PhD graduates. Any noticeable improvement in PhD quality will certainly require an uplift in stipends over and above those already announced up to 2003/04.

4.40 The actual level of stipend increase required will vary between particular areas of research and between different institutions, to reflect graduate salary expectations and living costs in the area, among other factors. This implies that institutions need to be able to respond to their particular market conditions; EPSRC's doctoral training grants[157] seem to be a good model for this. There is also a question of whether salary progression through a PhD should be introduced: this would reward progress by students, but given the

[157] A doctoral training grant provides the finance for a cohort of students within a university. Universities are able to decide on the level of stipend (at or above the national minimum); the project duration (up to 4 years full time support); the format (*e.g.* part-time, industrial placement), and to adjust the number and timing of awards within the year (so students can start PhDs throughout the year) and between years. Decisions on stipend and project duration can be balanced with considerations of the discipline, location and overall student numbers.
Further background information on doctoral training grants is available from
http://www.epsrc.ac.uk/epsrcweb/main/training/inuni/Scheme_Conditions.htm and from
http://www.epsrc.ac.uk/epsrcweb/main/training/inuni/34-99.htm.

importance of debt to potential postgraduate students it is important to pay enough up-front to service and/or pay off debt, if more indebted students are not to be deterred from PhD study.

Recommendation 4.1: PhD stipends

In order to recruit the best students to PhD courses, it is vital that PhD stipends keep pace with graduates' salary expectations, particularly given the increasing importance of student debt on graduates' career choices. It is also important that stipends better reflect the relative supply of, and market demand for, graduates in different disciplines. The Review therefore recommends that the Government and the Research Councils raise the *average* stipend paid to the students they fund over time to the tax-free equivalent of the average graduate starting salary (currently equivalent to just over £12,000), with variations in PhDs stipends to encourage recruitment in subjects where this is a problem. Furthermore, the Review recommends that a *minimum* PhD stipend of £10,000 is established, to ensure that HEIs do not use this extra flexibility to attract extra PhD students at the expense of quality.

4.41 Setting a higher levels of Research Council stipend (in particularly higher minimum stipends) should encourage other funders of PhDs to follow suit, if they wish to attract good-quality PhD students. (The Wellcome Trust already offers such stipends to its sponsored students.)

4.42 The Review is also concerned that the funding system currently incentivises HEIs to focus on the quantity, rather than quality, of PhD students. Responses to the Quinquennial Review of the Research Councils indicated that the number of PhD students was being increased at the expense of their quality, thus threatening the supply of high-quality researchers in the UK. A working party of the UK Life Sciences Committee in 2000 took a similar view.[158]

4.43 One reason for this behaviour on the part of English HEIs is that the funding system incentivises them to recruit more PhD students. Universities receive HEFCE funding for research students as follows:

- teaching funds for each first year student, on a similar basis to undergraduate students;
- supervision fees for each second and third year student (roughly equivalent in value to the teaching funds in year 1); and
- research ('QR') funding for each second and third year student, calculated on the basis that each student takes 3.5 years to complete the PhD.[159]

[158] *Postgraduate training in the life sciences*, UK Life Sciences Committee working party report, January 2000.

[159] Research funding is assigned to HEIs based on a department's Research Assessment Exercise (RAE) score and the number of research-active academic staff; each research student counts as 0.15 of a full-time academic. The money is calculated on the basis of each student doing 3.5 years' research, paid over 2 years.

4.44 The research funding and supervision fees can act as an incentive to employ as many PhD students as possible regardless of quality, since they are not linked to quality of supervision or training. The Review believes that additional funding for PhD students must go to improving the quality of the intake via raising stipends and better training, rather than being spent on increasing the number of lower-quality PhD students by offering more stipends, for example. HEFCE and the Research Councils should consider how best to achieve this and reduce any incentives to expand quantity at the expense of quality.

The quality of PhD graduates

4.45 Securing a high calibre of entrants to PhD programmes will not of itself ensure that PhD graduates are attractive to employers in education and in business. The definition of *quality* as it applies to PhD training and PhD graduates to some extent depends on what a PhD is meant to achieve.

4.46 The role and nature of the PhD has been the subject of continuing debate in the UK since its introduction in the early twentieth century. It was influenced both by the original German PhD, which emphasised preparation for becoming a scholar (*i.e.* an academic), and the PhDs developed in the US from the 1870s. The US PhDs were aimed at a continuation of the educational process rather than the development of qualitatively different aptitudes. This tension between the PhD as part of the cycle of education and the PhD as an academic apprenticeship is discussed by Blume.[160] Other studies contrast the elements of training (in the sense of developing the abilities of a researcher) with individual achievement (making an original contribution to knowledge; creativity), or – confusingly – between education (promoting broad understanding and capability) and training (learning specific skills).[161]

The PhD process

PhD training is conducted in the context of the relationship between the student and his or her supervisor, an academic with research interests similar to the student's. PhD students in SET generally join their supervisor's research group and begin a research project under his or her direction. The supervisor's role is to advise and support the student in learning to conduct original research.

PhD students are often officially admitted onto a university's MPhil programme to begin with. In order to progress to formal registration for a PhD, students must demonstrate their abilities, typically by a dissertation on their research so far and an oral examination. Successful students proceed to the PhD, while unsuccessful students may leave with an MPhil (if their work is good enough) or with no qualification. The student spends the next 2 years carrying out and writing up a research project, which is examined by thesis and by an oral examination (the *viva*).

[160] *The Role and Function of Universities: postgraduate education in the 1980s*, S Blume, OECD, 1987.
[161] *The Nature of the PhD: A Discussion Document*, Advisory Board of the Research Councils/OST, 1993.

PhD training is often delivered through the informal relationships between the student and other members of the research group, including (but not limited to) the supervisor. Particularly in larger groups, postdoctoral researchers can play an important part in developing a PhD student's skills. More formal training can take a number of forms, from advanced lecture courses to departmental research seminars, development workshops for interpersonal skills and instruction in the use of IT at a variety of levels.

4.47 Responses to the Review's consultation indicate that HEIs' definition of PhD *quality* has tended towards preparation for academic scholarship (in a fairly narrow sense, dominated by engagement in curiosity-driven research) rather than broader education and training. Research employers in HE and business both seek a balance of education and training; non-research employers that take on PhDs and postdocs unsurprisingly tend to value the broad educational elements over training in specific scientific skills or techniques. In general, employers' opinion of PhD students' scientific research and technical skills – with the possible exception of practical skills such as use of the latest equipment – is very high, while interpersonal skills, and students' awareness of these abilities, are felt to be less good.[162]

4.48 One perception of business respondents to the Review is that PhD training and the postdoctoral research experience are not adapted to businesses' R&D needs, but reflect only the aims of the academic community. This perception seems if anything to have grown, which is surprising, given the increasing awareness of the need for business, enterprise and communication skills training in higher education. (The new Science Enterprise Centres[163] are beginning to play an important role in providing training in these areas.) It is possible that business expectations have increased, for example as a result of changes in the education systems of other developed countries, and also that the skills profiles of many jobs within business have altered, requiring greater breadth of skills and aptitudes. Another explanation would be that the quality of those attracted onto PhD courses has altered in this respect.

4.49 There is also cause for concern that UK PhD study and postdoctoral work is not particularly good training for would-be academic staff, because of its near-exclusive focus on research and its lack of preparation for other elements of the academic role including teaching, knowledge transfer/reach-out activity and student welfare.

[162] Very similar problems were identified in *The Chemistry PhD – the Enhancement of its Quality*, Royal Society of Chemistry, April 1995; however, the importance of the issue seems to have increased since then.

[163] See http://www.dti.gov.uk/ost/ostbusiness/sec.htm for further information.

4.50 Current arrangements do not therefore give satisfactory training in communication (including teaching), management and commercial awareness to fully equip researchers for the professional demands of modern academic life[164] and employment in R&D. A 1998 survey of all HEIs and EPSRC-supported research students revealed considerable variance between HEIs and university departments in the provision of training in these transferable skills. Largely as a result of these deficiencies, PhD graduates rarely attract a salary premium from employers.

4.51 Ways in which the quality of PhD graduates could be improved include:

- improving the quality of the intake by making PhD study more attractive, as discussed above;
- stronger quality control in PhD training by institutions, particularly in registration of students for the PhD degree;
- more emphasis by institutions on training in transferable, non-technical skills within current PhDs, and on promoting the value of this training to PhD students;
- giving individual PhD students more control over the nature of their training; and
- the introduction of longer (4 year) PhDs, with a higher component of skills training, advanced education in relevant scientific topics, and/or more challenging research projects.

These are discussed in more detail below.

Stronger quality control in PhD training

4.52 Learning transferable skills should be an important part of the PhD process. Today's PhD student is the highly-skilled academic or business researcher of tomorrow, and will need interpersonal and management skills to fill these roles effectively. HEIs have a vital part to play in educating their students about the benefits of such training, and must do more to encourage participation and provide high-quality and appropriate training. The recent HEFCE Review of Research recommended establishing threshold standards of good practice in research training provision:

"The HEFCE, together with the Research Councils and other stakeholders such as industry and charities, should develop minimum requirements which departments would need to satisfy in order to be eligible for HEFCE funding for postgraduate research training. The research assessment process should be extended to establish whether departments comply with these minimum standards."

[164] *The Chemistry PhD – the Enhancement of its Quality*, Royal Society of Chemistry, April 1995, http://www.rsc.org/lap/polacts/phd.htm contains an excellent discussion of this problem and how it should be addressed.

4.53 The Joint Funding Councils Review of Research Training, begun in late 2001, is seeking to determine suitable standards. The Review has identified a number of areas to be dealt with:

- ensuring PhD students' work is creative and original;
- supporting and rewarding good PhD supervision; and
- increasing students' participation in and learning from training in transferable skills.

It is important that these standards are seen to be challenging rather than a simple endorsement of current practice.

4.54 One particular concern which has come to the Review's attention is that institutions are insufficiently searching in testing PhD students' abilities. As part of their quality control procedures, most institutions register new PhD students for a lower degree such as an MPhil. On satisfactory progress (generally demonstrated by a written report and an oral examination and/or presentation) the student is formally registered for or 'transferred' to the PhD degree.[165] The Review is concerned that in some cases this test does not require the student to demonstrate sufficiently the qualities of creativity and original thought which are vital to research and much prized by employers. For this reason, the Review is particularly keen to see a strengthening of quality assurance procedures.

4.55 The function of a supervisor in supporting and mentoring students is vital in developing them into capable researchers. It is the supervisor who is best placed to develop a research student's judgement about research method, and to stimulate creativity and analytical thinking. Good supervisors also play a role in helping students identify suitable training, and in encouraging them to make the most of such opportunities. Poor supervision (including the deliberate choice of relatively undemanding projects for PhD students, a problem which seems commonest in large research groups) can potentially suppress all of these desirable qualities.

Provision of training in transferable skills

4.56 The Research Councils, which collectively are the single largest PhD funder in the UK, are major influences on PhD training standards. All Research Council students have access to a special week of transferable skills training and careers advice under the Research Councils Graduate Skills Programme (RCGSP) described below.[166] The Research Councils also published jointly a Concordat setting out the skills a PhD student should acquire as part of their training. The recent Quinquennial Review of the Research Councils (December

[165] The language used to describe this 'transfer' process varies greatly between universities, but the principles – as outlined – are broadly the same.

[166] All EPSRC-sponsored students are now required to attend a Graduate School, or an equivalent training programme, during the second or third year of a 3-year PhD. The other Research Councils strongly recommend participation.

2001) recommended that the Research Councils should monitor the quality of research training and career development, and needed to examine how training could better meet the needs of employers, without jeopardising high quality research content.

4.57 The Graduate Schools offered by the RCGSP are five-day residential workshops at which PhD students – working with young managers and under the guidance of a course director and tutors – develop their team-working and communication skills. This is achieved using 'active learning', a mixture of case studies and business games including simulations relating to research and development, product development, marketing and crisis management. Career development and awareness is promoted through hearing about the experiences of the young managers and in sessions on interviewing and CV-writing skills. Participation rates for Research Council students at the largest Research Council-funded HEIs are given in Table 4.2.

Table 4.2: Uptake of RCGSP places by SET students, 2001

Institution	RCGSP attendance Per cent
University of Sheffield[167]	70
University of Birmingham	55
University of Nottingham	55
University of Edinburgh	45
University of Leeds	45
University of Manchester	40
University of York	40
University of Cambridge	35
University of Oxford	35
UMIST	33
University of Liverpool	33
University of Bristol	33
University College London	33
University of Newcastle	30
Imperial College of Science, Technology and Medicine	30
University of Glasgow	25
University of Southampton	25
University of Warwick	20
University of Wales, Cardiff	15
University of Sussex	10
Average	**35**

Source: Research Councils Graduate Schools Programme – figures for the 20 largest Research Council[168] funded HEIs only (unpublished data).

[167] The University of Sheffield accepts RCGSP attendance against its compulsory credit-based Research Training Programme.

[168] Students funded by BBSRC, EPSRC, MRC, NERC & PPARC.

4.58 The difference in RCGSP participation rates between the three institutions listed at the top of Table 4.2 (55 per cent or more) and the three at the bottom (20 per cent or less) may in part be due to alternative skills training provision in the latter. However, the disparities suggest that institutional attitudes play a major part in ensuring students engage in suitable training, and that many institutions need to take PhD training more seriously.

The role of the individual research student in training

4.59 Comments made to the Review by businesses, universities and others have mainly concentrated on how the providers of research training should alter the PhD. However, the effectiveness of training also critically depends on the individual. Students need to be aware of the nature and value of their own transferable skills, and to take ownership and responsibility for their learning. If this is not encouraged, the PhD student can feel himself or herself to be a passive client of the university, to be trained according to a particular imposed programme.

4.60 The Review Team's visits to HEIs indicated that even in universities where training is provided and a "charter" of PhD students' entitlements exist, awareness of this entitlement is not widespread. The Review also encountered some instances of research students wanting to undertake training which was available within the university, but was not accessible to them. The skills students wished to acquire varied considerably: one physicist wanted to train as a teacher (PGCE) while studying for a PhD, while others wanted to study languages or specialist IT courses, for example. The Review is concerned that PhD students wishing to obtain training of clear professional relevance (present or future) have difficulty doing so, although the potential cost implications for universities of providing more free-form and/or extensive training are acknowledged.

4.61 Clearly there is a place for structured training and education, using the institution's experience to develop courses for the benefit of the individual learner. However, given both the individual nature of researchers and research projects, and the increasing need for people to take charge of their own learning throughout their lifetime, there would be value in placing more control of training in the hands of the student rather than the institution.

Recommendation 4.2: PhD training elements

Despite the welcome current moves by the Funding Councils to improve the quality of PhD training, institutions are not adapting quickly enough to the needs of industry or the expectations of potential students. The Review therefore believes that the training elements of a PhD – particularly training in transferable skills – need to be strengthened considerably. In particular, the Review recommends that HEFCE and the Research Councils, as major funders of PhD students, should make all funding related to PhD students conditional on students' training meeting stringent minimum standards. These minimum standards should include the provision of at least two weeks' dedicated training a year, principally in transferable skills, for which additional funding should be provided and over which the student should be given some control. There should be no requirement on the student to choose training at their host institution. The minimum standards should also include the requirement that HEIs – and other organisations in which PhD students work – reward good supervision of PhD students, and ensure that these principles are reflected in their human resources strategies and staff appraisal processes.

Furthermore, in order to assure employers of the quality of PhD students, as part of these standards the Review recommends that institutions should introduce or tighten their procedures for the transfer of students to the PhD. In particular, the Review believes that HEIs must encourage PhD projects that test or develop the creativity prized by employers.

The duration and content of the PhD

4.62 One possibility which a number of respondents to the Review explored was that the composition and length of the PhD should be altered. This would reflect the 'real' length of the three year PhD (the majority of students take between 3-4 years to complete a PhD, as illustrated for Research Council students in Table 4.3, and very few take less[169]) and could potentially incorporate more explicit training and education and/or more challenging projects. A longer PhD could be a formal programme of four years or of some intermediate length between three and four years, for example. The Quinquennial Review of the Research Councils (2001), on the other hand, opposed unduly extending the PhD period to achieve this, although it also noted that "it is appropriate that subject discipline should predicate different approaches to postgraduate training".

[169] See for example *Career Paths of a 1988-1990 Prize Student Cohort*, The Wellcome Trust (March 2000), which shows around 80% of a sample of 125 bioscience PhD students taking 3-4 years to complete a PhD (Figure 3.1 in Chapter 3) but only 3 out of 125 completing within 3 years.

Table 4.3: Thesis submission rates for Research Council students, 1994-1999

PhD commenced:	1990	1991	1992	1993	1994	1995
Proportion submitted within 4 years, i.e. by:	**1994 per cent**	**1995 per cent**	**1996 per cent**	**1997 per cent**	**1998 per cent**	**1999 per cent**
BBSRC	70	77	77	83	85	86
ESRC	73	71	75	80	75	80
MRC	64	58	67	69	72	73
NERC	73	72	71	73	73	67
EPSRC	67	68	67	73	72	74
PPARC	82	82	81	80	81	83

Source: ESRC.

4.63 There are a number of existing or developing models for 4-year PhDs in the UK. The New Route PhDs developed in ten English HEIs using HEFCE funding are intended to be integrated PhD courses somewhat like the US PhD, with a significant taught component. The Engineering Doctorate is more established and highly respected, with a particular emphasis on business involvement and transferable skills, including management. A '1+3' model for PhD study, whereby a student completes a 1-year MPhil or MRes course before beginning a 3-year PhD[170] would also be feasible.[171] Other uses for an extended PhD period could include experience of work outside the research group (in a company or another research group), teacher training (suggested to the review by both students and HEIs) and – if the project generates commercially valuable knowledge – the technology transfer process. There is also the potential for longer and more challenging research projects to be undertaken, while still allowing more time and flexibility for other training and development than a 3-year programme. The arguments for retaining a 3-year PhD versus adopting a 4-year PhD, *assuming the same length of undergraduate course in both cases*, can be summarised as follows:

Table: 4.4: Comparison of benefits of 3 year and 4 year PhDs

Advantages	Disadvantages (of 4 year PhD over 3 year)
Student has more time for research and training	Student takes longer to enter labour market; debt will deter more students
Allows more ambitious projects	Students' work may be slower or may 'drift' as urgency of shorter PhD is lost
May reduce 'overrun' – PhD students usually take longer than 3 years to complete a PhD and so more students will be able to complete in the time available	Overrun may remain or even get worse as supervisors require 4 years' lab work and writing up takes longer as there is more material
Closer to European and world standard length of PhD	Possible loss of UK competitive advantage if high-quality UK 3-year PhD disappears
Better trained and more experienced (hence, more valuable) PhDs	Additional cost per PhD

Source: Review.

[170] The 1+3 model is common in arts and social sciences; ESRC now requires its students to follow a 1+3 route.

[171] According to the UK Life Sciences Committee Working Party report *Postgraduate Training in the life sciences*, over 20 per cent of BBSRC PhD students have a postgraduate Masters qualification – mostly an MSc.

Possible models for a 4 year PhD

4.64 As noted by the most recent Quinquennial Review of the Research Councils, different patterns of PhD provision may be appropriate in different subjects. In particular, subjects where 3-year undergraduate courses predominate, such as the biological sciences, may derive particular value from operating 4-year PhD courses. In engineering, on the other hand, the 4-year MEng undergraduate degree is the norm for chartered engineers, and 4-year PhDs may be of more limited value.

The 'early entry' 4-year PhD

4.65 Students entering a 4-year PhD from a 4-year undergraduate programme would have spent 8 years or longer in higher education, and thus would not have participated in the labour market or begun to pay off student debt until their mid-20s at the earliest. One way of circumventing the late entry to the labour market of a 4-year PhD is to start the PhD earlier. It would be possible for HEIs to identify able students and encourage them to graduate with a BSc after three years and begin a four year PhD,[172] as an alternative to a four year undergraduate degree plus a three year PhD. Under these arrangements each student would do around 15 extra weeks' research and training (the difference between a 30-week, 9 month undergraduate course and a 12 month PhD) without extending the overall seven year duration of study.

4.66 While this model helps individual HEIs recruit more students from their undergraduate supply, it also inhibits the flow of students between institutions, as it ties undergraduates who might have studied at other universities into their 'home' institution. Students leaving after year 3 of a 4-year undergraduate programme with a Bachelors degree may also be perceived as having an inferior qualification, particularly when the undergraduate Masters has professional significance (such as the MEng in engineering). Although there may be individual cases where this method can help recruit and train better researchers, its drawbacks mean it is not a suitable general model for PhD provision in the UK.

The Wellcome Trust PhD

4.67 The key feature of the 4-year Wellcome Trust PhDs in life science is an introductory year involving three 12-week advanced courses and associated practical mini-projects, followed by three months learning research techniques and developing a thesis proposal. This helps inform students' choice of research projects (and allows more complex projects) as well as bringing students from different backgrounds up to speed with modern molecular and cellular biology. The Wellcome Trust also offers students a Science Communication course as part of the 4-year programme.

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[172] This mechanism is already used by some HEIs to select 3-year PhD students from their third-year undergraduates.

The New Route PhD

4.68 The New Route PhD – developed in ten English universities – combines a specific research project and research training (comprising approximately 60-70 per cent of the programme) with a programme of formal coursework throughout the programme. The idea is for students to develop a fuller and individually-tailored range of skills, including from discipline-specific specialist taught courses and broader skills (*e.g.* management and enterprise) training, alongside research training and a major piece of research. The length of a New Route PhD would normally be four years (or potentially three years for students with Masters' level entry qualifications).

Flexible funding to cover a range of PhD durations

4.69 There are good arguments for extending the period of PhD training (and funding) in order to increase the depth and breadth of skills acquired – through spending time in industry, for example – and to attract potential students who would value this approach more than a traditional three-year PhD. However, increasing the length of time before a student can begin paid employment can be a disincentive to recruitment, and there is international demand for 3-year UK PhD courses. It is therefore clear that a mixture of PhD provision, both in length and in content, is necessary to attract the full range of potential researchers into PhD training.[173] Institutions should be funded and encouraged to develop a diversity of approaches to the PhD. All PhDs should be examined to the same standard in the final thesis and *viva,* although longer PhD programmes would involve additional elements.

4.70 The majority of PhD students take between three and four years to complete their studies. The Review's discussions with PhD students indicated that most students expected to need extra time to write up their PhDs at the end of three years. The Review believes that the funding system should acknowledge this, and provide institutions with sufficient financial flexibility to allow them to support students whose projects do not fit neatly into 3- or 4-year programmes. This will allow institutions to set more challenging projects without imposing severe financial consequences on the student if the project over-runs, or to incorporate advanced courses and additional transferable skills training.

4.71 HEFCE already allocates research funds to HEIs on the basis that a PhD takes an average of 3.5 years, and could pay the supervision fees for second and third year students on a similar basis. Research Councils currently provide funding (stipends etc.) on the basis of three years of study, although the EPSRC doctoral training grant model allows more flexibility. Allocating PhD

[173] Comments by Wellcome Trust PhD students on a mixture of three and four year PhD courses indicate that both approaches appeal to some students but not to others; see *Review of Wellcome Trust PhD Research Training: The Student Perspective*, The Wellcome Trust, March 2000 for further details.

student support by HEFCE and the Research Councils to institutions on the basis of 3.5 year average course durations would give them the ability to vary:

- the length of formal course offered (3 years or 4 years, or of intermediate length);
- the length of support to individual students, to allow more flexibility to engage in multidisciplinary projects and training, for example, or to provide additional paid time for students to write up their projects; and
- stipend levels (subject to a minimum level, as discussed previously).

Recommendation 4.3: Length and nature of PhD programmes

The Review believes that measures should be put in place to help nurture a diverse range of PhD programmes to train able students in research methods and technical skills, and help them acquire the advanced knowledge and transferable skills they will need in their future careers. This should include encouraging part-time working and the gaining of experience in business R&D. Individual institutions should be given flexibility to offer a range of provision. The Review therefore recommends that:

- the Government and the Research Councils should fund their present numbers of PhD students on the basis that the average full-time student requires funding for $3^{1}/_{2}$ years;
- it should be possible for the institution to use the funding flexibly to run three- and four-year full-time programmes (and also study of intermediate length) to support longer and more challenging projects, advanced courses and transferable skills training;
- both three- and four-year courses should be examined to the same standards, which should be at least as high as the current standards; and
- students should be able to exit early from PhDs (subject to satisfactory performance) with an MRes or an MPhil.

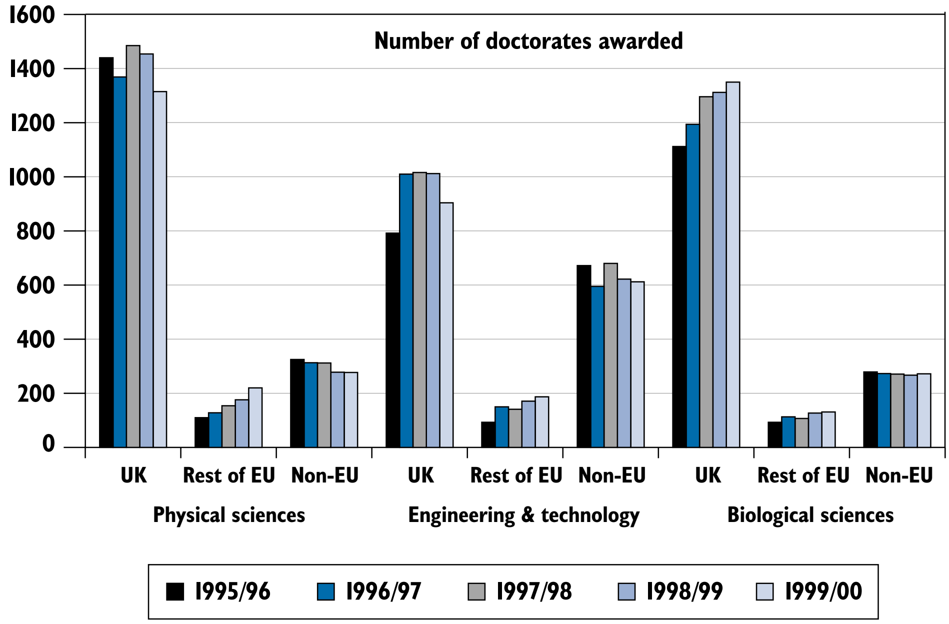
The Review believes that the EPSRC's doctoral training grants system represents a good way of achieving this flexibility, and urges other Research Councils to implement similar mechanisms.

Retention of PhD students in the UK

4.72 It was suggested by a number of respondents to the Review's June 2001 consultation document that the UK is increasingly losing its science and engineering PhD graduates overseas. It is also the perception that overseas students who take PhDs in the UK do not remain once they have obtained their PhD. On the other hand, some respondents pressed for Research Council funding to cover maintenance awards for EU postgraduate students, wanting to encourage these students to come to the UK to improve the quality of intake onto PhD programmes.

4.73 There are two aspects to the retention of PhD students in the UK: the number of students of UK origin taking PhDs in science and engineering, and the net flow of people with such PhDs into and out of the UK. Retention is itself a difficult concept, as in the global market for researchers people will often live and work outside their country of origin. Mobility of researchers is encouraged both within the EU and within the global research community. Furthermore, tracking the movement of skilled researchers is extremely difficult.[174] In particular, information on postgraduates' first destinations can be misleading, particularly for researchers, for whom a postdoctoral post outside the UK (*e.g.* in the US) is often encouraged as a good career move.

Figure 4.7: Number of UK doctorates by discipline and student origin, 1995/96 to 1999/00



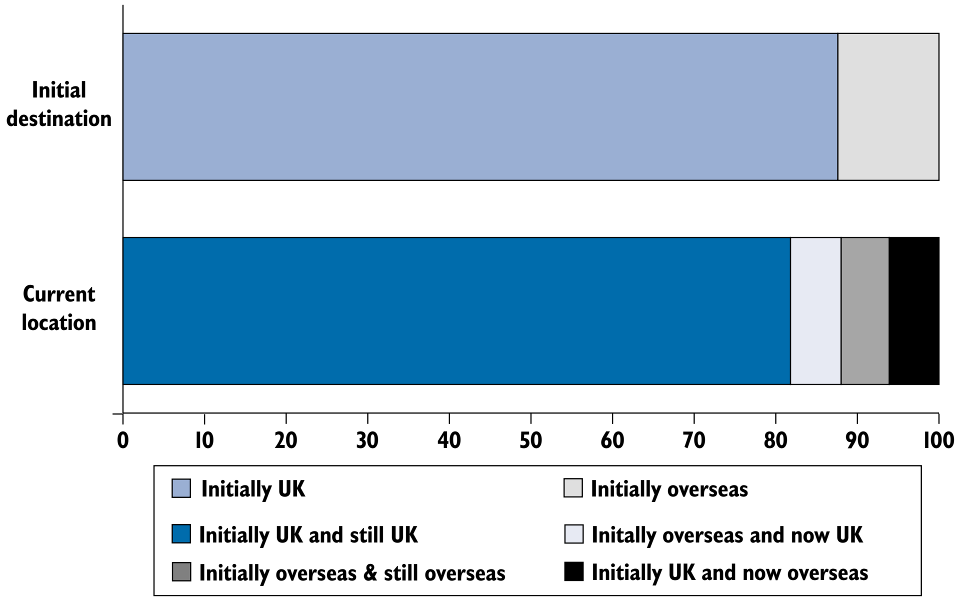
Source: HESA Student Returns (unpublished DfES data) – excludes students gaining doctoral qualifications from dormant status (i.e. those who were not students immediately prior to award and whose origin was therefore unknown).

4.74 Of those students who leave the UK on completion of a PhD, many return quite quickly; a study by EPSRC of career progress for its postgraduates 6-7 years after the end of the studentship showed that a large proportion (almost 15 per cent) of chemistry PhDs went to the US as a first destination, but over half of these had returned to the UK within the period of the study.[175] This is illustrated in Figure 4.8 below:

[174] Canberra Manual, OECD.

[175] *Where do EPSRC students go?*, Martin Dunn, EPSRC, September 2000.

Figure 4.8: Location of first and current jobs of EPSRC postgraduates



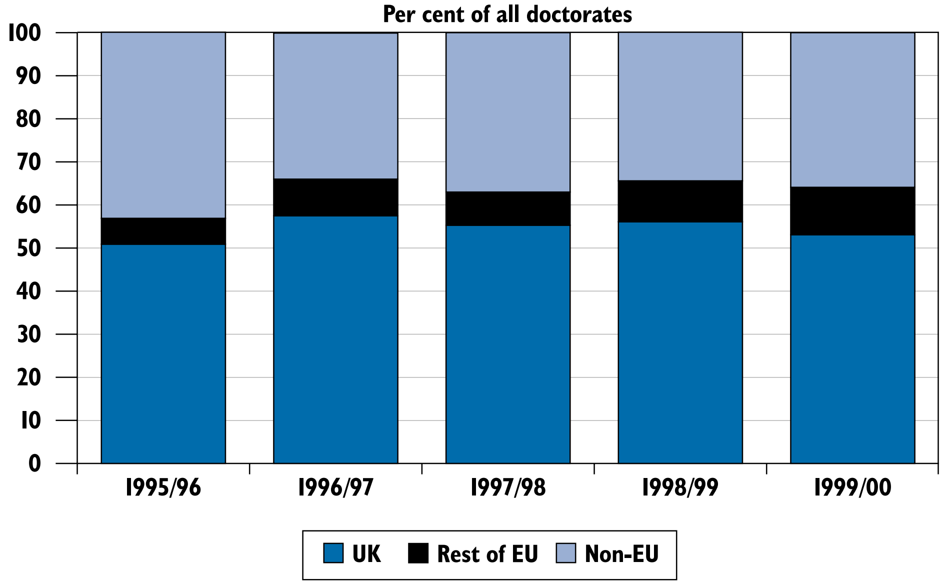
Source: Where do EPSRC students go?, Martin Dunn, EPSRC, September 2000.

Non-UK PhD students studying in the UK

4.75 In the UK, the greatest proportion of students from outside the UK is found on engineering courses. Figure 4.9 illustrates that typically 40 per cent to 50 per cent of engineering PhD students in the UK are not of UK origin. This level of participation by non-nationals is not exclusive to the UK; in 1995, 40 per cent of all US science and engineering doctorates were gained by citizens of foreign countries (up from 27 per cent ten years previously) and 56 per cent of engineering doctorates awarded in 1991-1995 were gained by non-US nationals.[176] A recent report in *Physics Today* (May 2001) noted that over half of the pool of US PhD students in physics were foreign.

[176] National Science Foundation/SRS, Survey of earned doctorates for the years 1991-95.

Figure 4.9: Proportion of UK doctorates in engineering by student origin, 1995/96 to 1999/00



Source: HESA Student Returns (unpublished DfES data) – excludes students gaining doctoral qualifications from dormant status (i.e. those who were not students immediately prior to award and whose origin was therefore unknown).

4.76 It is not immediately obvious whether high numbers of overseas students represent a problem for the UK or a benefit. From a UK skills perspective, too high a proportion of non-UK students may cause difficulties. The global market for scientists and engineers notwithstanding, there is a tendency for even the highly skilled to remain in or return to their country of origin. Researchers of other nationalities actively value the opportunity to hone their scientific English and hence seek out opportunities to study in anglophone countries such as the UK, but will often return to their country of origin within a few years. If too many students from outside the UK occupy PhD places which would otherwise have been taken by able UK students, there will be a skills cost to the UK, as those non-UK students are more prone to leave the UK than 'home' students.

4.77 However, if most of the students coming to the UK are self-funded or are filling places which UK students would not fill (because demand from potential students is low, and/or good candidates are not available) then the UK benefits. Not only does it gain from the students' research outputs while they remain in the UK, but the introduction of individuals with a different set of skills and approaches from UK students will lead to beneficial cross-fertilisation of ideas and approaches and strengthen both UK research and UK research training. The presence of non-UK students may also lead to longer-term benefits of international networking between former PhD students. Furthermore, non-EU students are net contributors to an HEI's income, and may help maintain the viability of a university department that might otherwise close.

4.78 In conclusion, the presence of non-UK students in the UK is almost wholly beneficial, as long as there is a sufficient supply of UK scientists and engineers (or of scientists and engineers wishing to work in the UK). The Review has not found evidence that the presence of large numbers of non-UK students indicates anything other than the weak demand from the most able UK students to study for a PhD, and so the Review believes that action to render PhDs more attractive to UK students is more important than the origins of non-UK PhD students. However, it is important that the situation should be monitored to ensure that enough good-quality PhD students from the UK are trained in the UK and that non-UK students are encouraged to remain and enabled to do so by the work permit system. Chapter 6 deals with the issue of work permits in more detail.

4.79 This argument deals only with supply direct from higher education. Once researchers are in the labour market, the responsibility to recruit and retain them in R&D posts must lie with the employers – in both HE and business – collectively. Employers also have a shared responsibility with the researchers they employ for the continuing professional development (CPD) of those researchers.

Maintenance awards for EU postgraduates

4.80 Many universities interviewed by the Review Team or which responded to the consultation said that a lack of sufficiently high-quality UK students wishing to do PhDs encouraged them to recruit students from overseas. EU students often wished to undertake postgraduate training in the UK, but Research Council grants would pay university fees but no maintenance support (stipend). Universities have therefore found themselves either leaving studentships unfilled or having to pay EU research students maintenance from other resources.

4.81 In order to allow HEIs to attract top EU students, it has been suggested that the Research Councils should be given the freedom to pay maintenance awards to PhD students from elsewhere in Europe. One possible concern is that additional expenditure on EU students would reduce the number of studentships Research Councils can offer, and/or increase the flow of EU students at the expense of (possibly less-qualified) UK students. It is important that any change to Research Councils' practice should not reduce the supply of PhD holders in the UK workforce.

Recommendation 4.4: EU PhD students

The Review would welcome the extension of PhD maintenance awards to EU students by the Research Councils as a means of maintaining and improving the quality of research in the UK. The effect of this on the number and quality of UK PhD students should be closely monitored in order to ensure sufficient supply of PhD holders for the needs of the UK economy.